3.1 The effect of dam removal on ecosystem patterns and processes in the Elwha River

George R. Pess

May 4, 2015

USGS
science for a changing world

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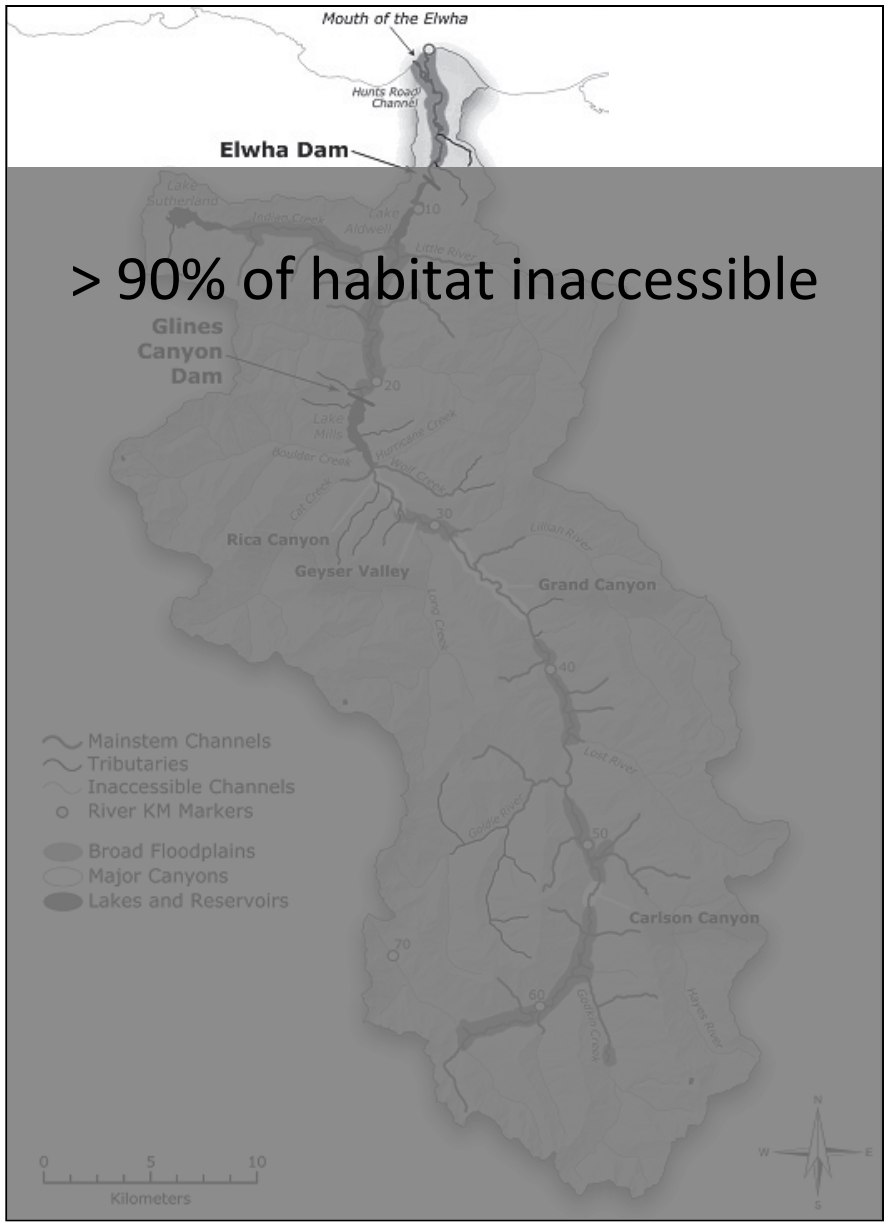
The Elwha River Basin

Photos: John Gussman

Impacts of the Dam – Fish Passage



Elwha River fishes

Coho salmon

Pink salmon

Chinook salmon

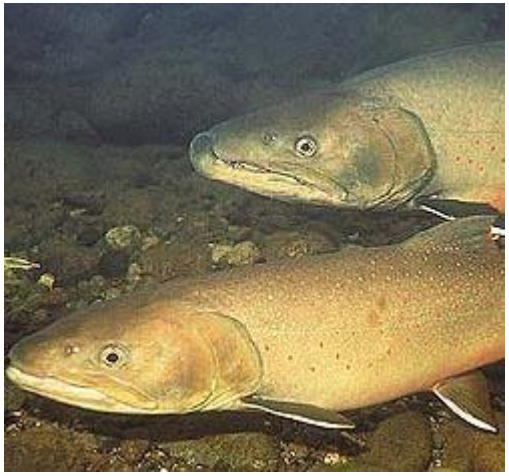
Steelhead

Chum salmon

Sockeye salmon

Sculpin spp.

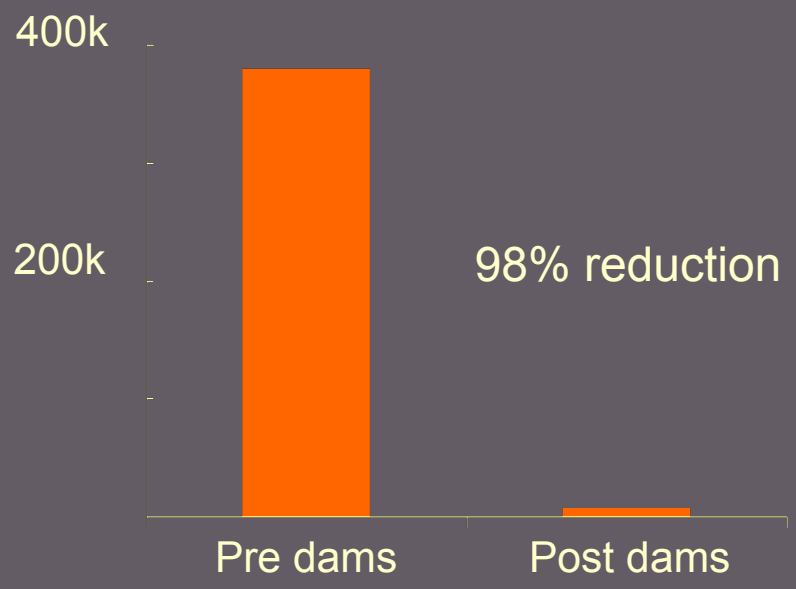
Bull trout



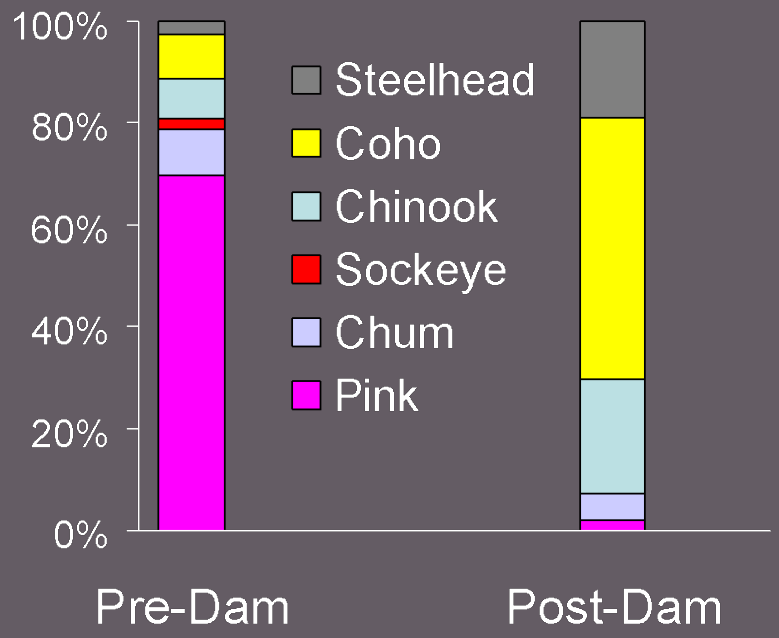
Brook trout

Impacts of the dams on Elwha River salmon

Total population decline



Shift in species composition



All native populations are very low in abundance

Pess, G. R., M. McHenry, **T. J. Beechie, J. R. Davies**. 2008. Biological impacts of the Elwha River dams and potential salmonid responses to dam removal. Northwest Science, 82(sp1):72-90.

Current Elwha River salmon population estimates

Species	Estimated population size below dams	% Hatchery
Spring Chinook	Unknown	Unknown
Summer/Fall Chinook	~2,000	**~75**
Coho	~2,000	**~76**
Chum	~100	0
Pink	~100	0
Sockeye	~25	0
Winter steelhead	~300	**~?**
Summer steelhead	~50	0
Sea-run cutthroat	Unknown	0
Char	~500	0

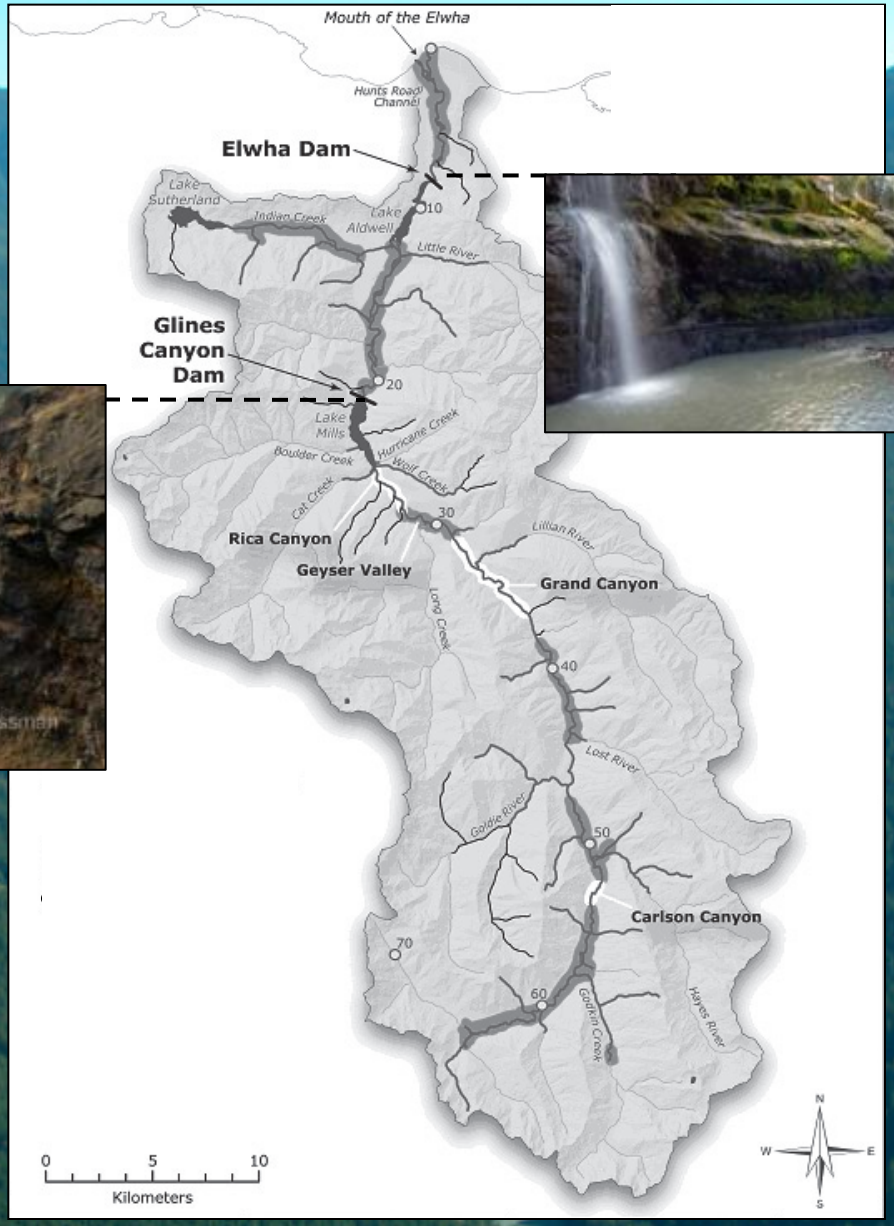
Pess, G. R., M. McHenry, **T. J. Beechie, J. R. Davies**. 2008. Biological impacts of the Elwha River dams and potential salmonid responses to dam removal. Northwest Science, 82(sp1):72-90.

Elwha River Ecosystem and Fisheries Restoration Act

"…for the removal of the dams and full restoration of the Elwha River ecosystem and native anadromous fisheries."

102nd Congress of the U.S.A.
January 3, 1992

The Elwha River Basin



Photos: John Gussman

What's going to happen to all the sediment?

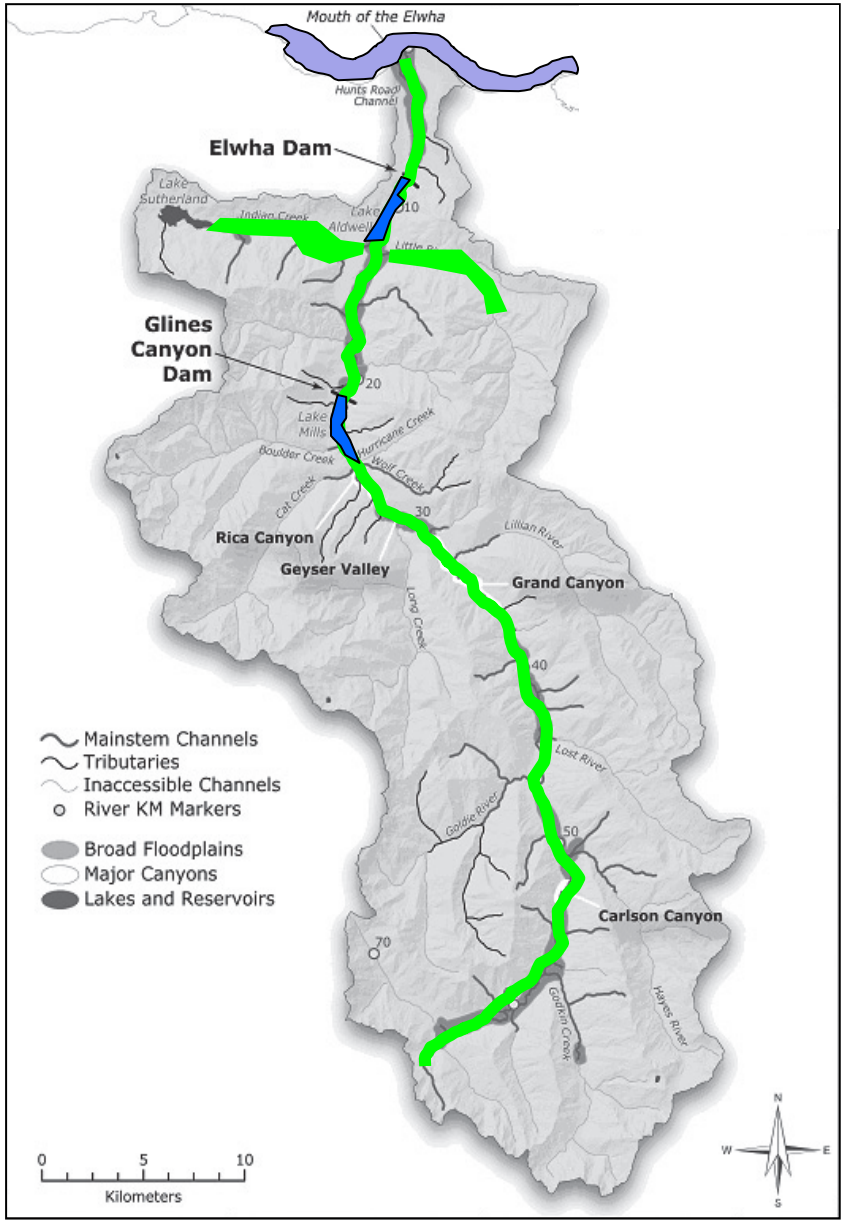
~ 20 million m^3 of sediment accumulated in reservoirs

- ~ 54% fine, ~46% coarse
- ~40% predicted to erode downstream

Predictions

- suspended-sediment > 10,000 ppm
- temporary deposition of fines in pools
- more dynamic floodplain
- bed aggradation in lower river
- beach formation in estuary

What has occurred with the removal of the Elwha River dams?



Location

- Dams & former reservoirs
- Nearshore
- River ecosystem

Processes

Sediment dynamics

Fish recolonization

Benthic foodwebs

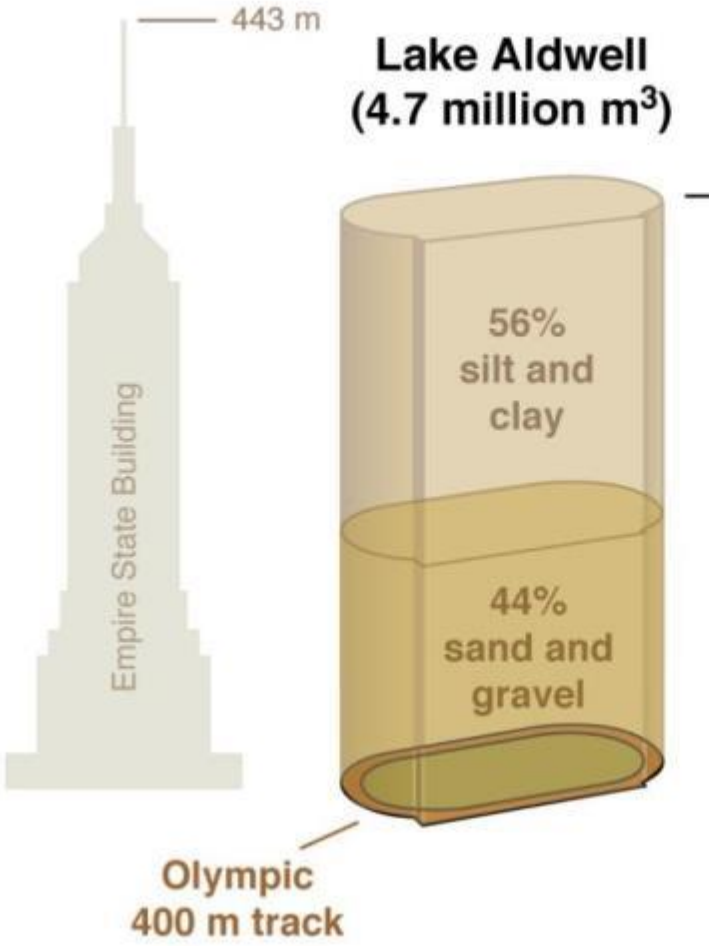
Terrestrial linkages

Revegetation

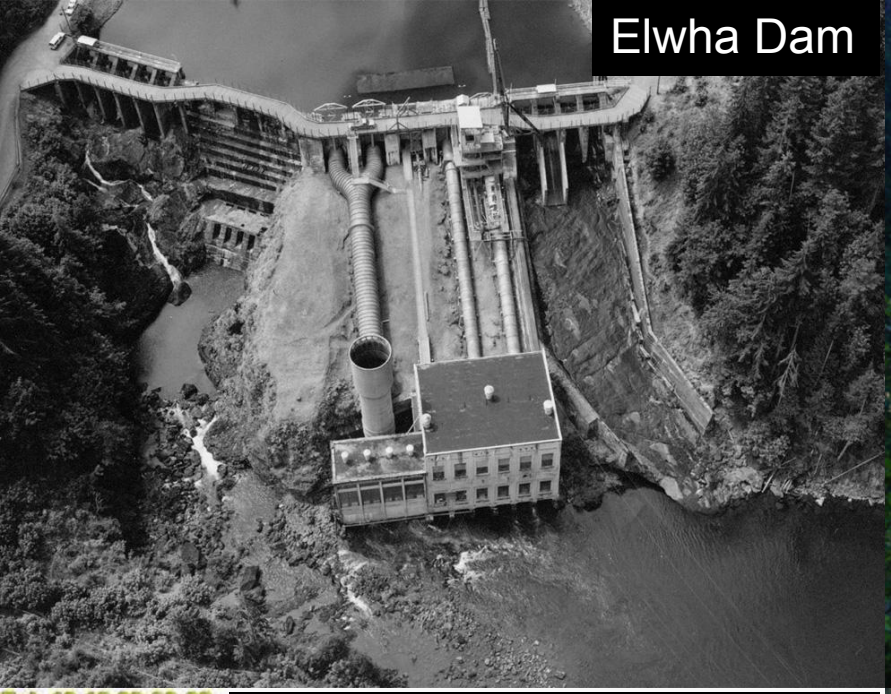
Elwha Dam removal

Before Dam Removal: September, 2011

Elwha Webcams courtesy NPS



- Completed in 1912
- 108 ft concrete gravity dam


Elwha Dam


Elwha Dam – September 2011


Elwha Dam – February 2012

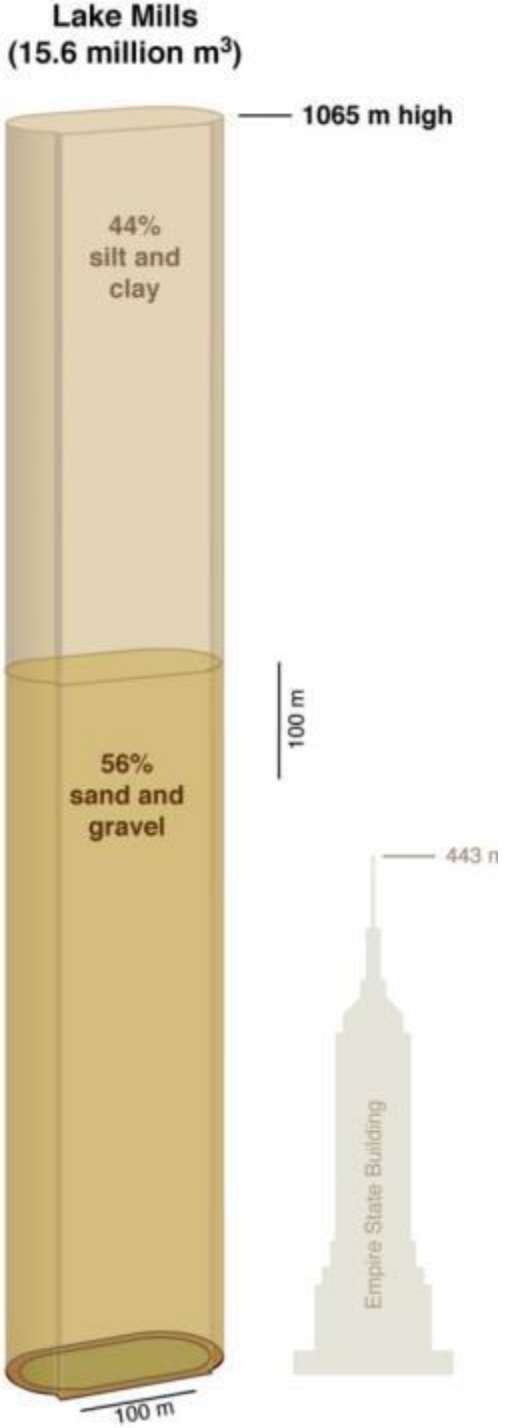

Elwha Dam –
August 2012

Glines Canyon Dam removal

Before Dam Removal: September, 2011

Elwha Webcams courtesy NPS

- Completed in 1927
- 210 ft concrete arch dam




Glines – September 2011


Glines – January 2012

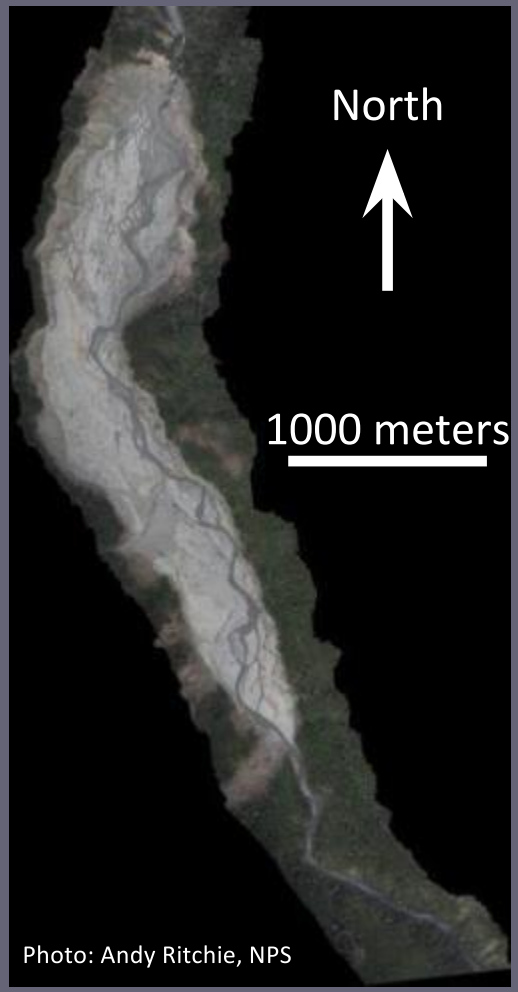

Glines – August 2012


Glines – May 2014

Glines Canyon Dam

Photo by Brian Cluer

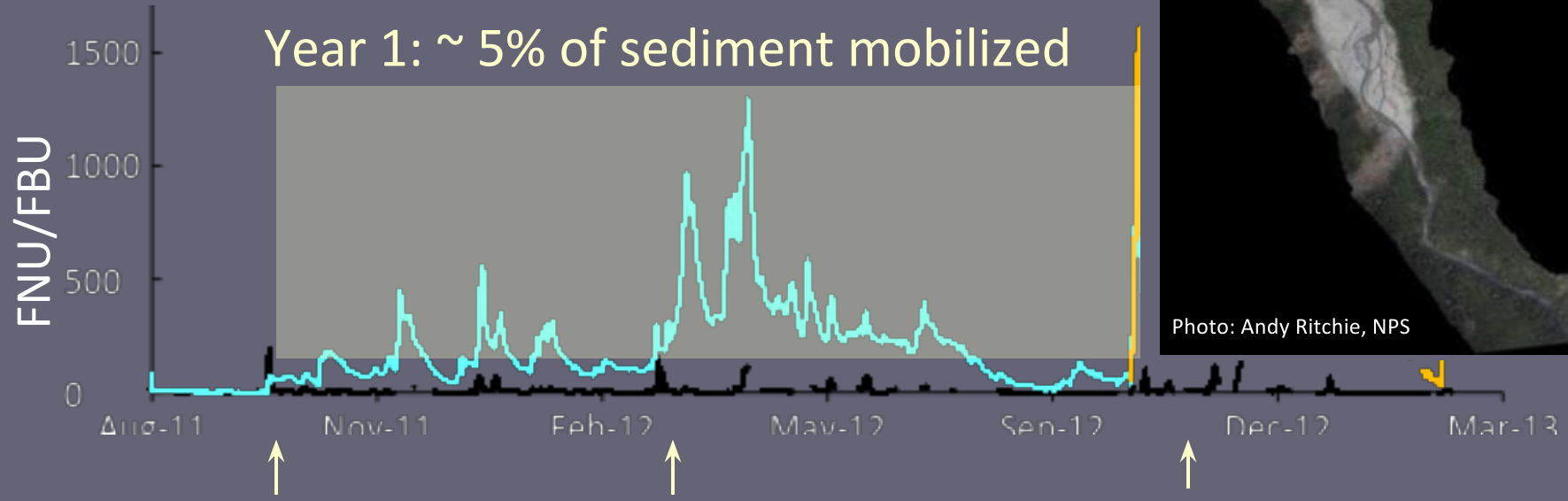
How has sediment supply changed?



Above Dams

Below Dams

Year 1: ~ 5% of sediment mobilized



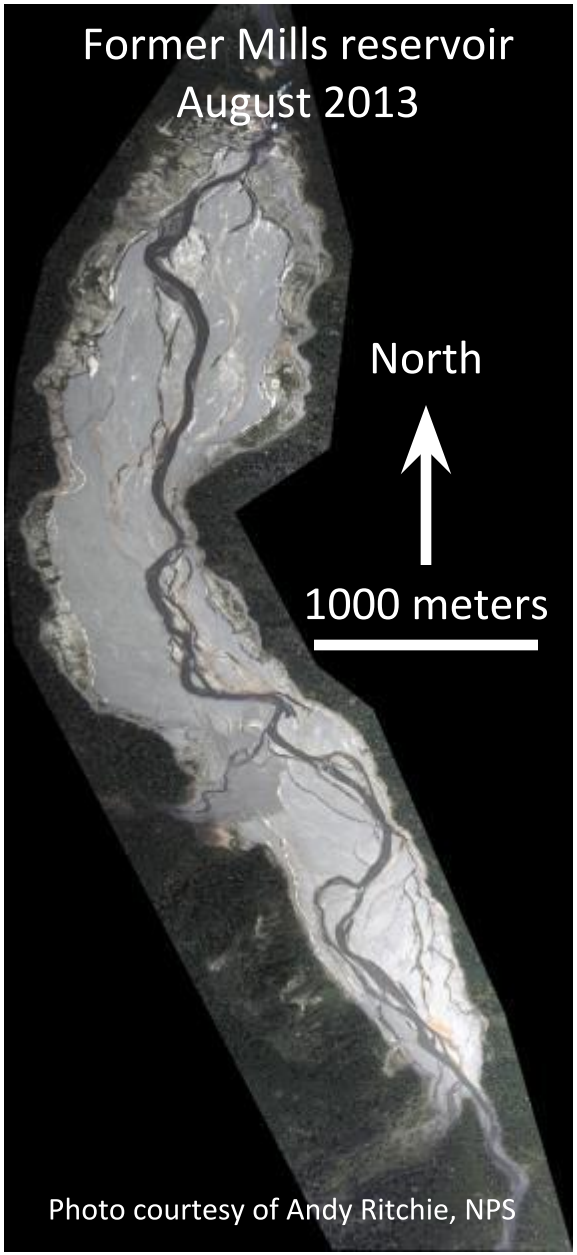
Dam removal begins

Elwha Dam removed

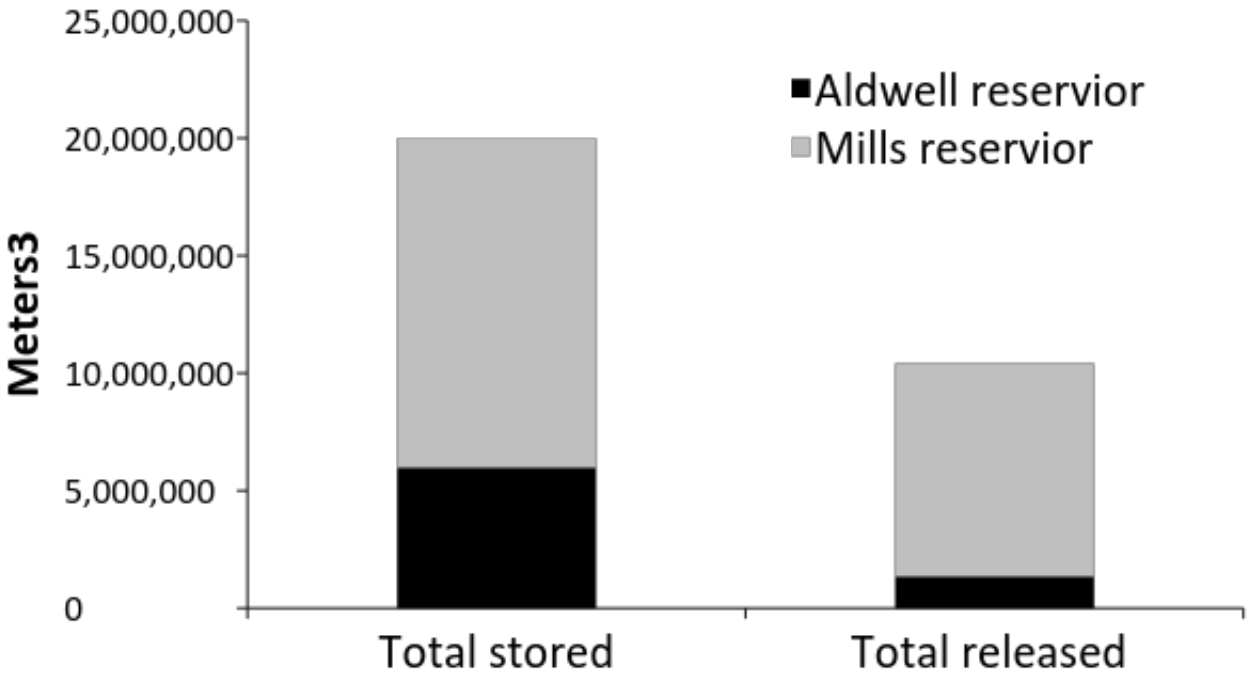
Lake Mills gone

Datasource: USGS

How much sediment has been released?



~52% released as of October 2013



Warrick, J.A., Bountry, J.A., East, A.E., Magirl, C.S., Randle, T.J., Gelfenbaum, G.R., Ritchie, A.C., **Pess, G.R.**, Leung, V., and Duda, J.J. 2015. Large-scale dam removal on the Elwha River, Washington, USA: source-to-sink sediment budget and synthesis. Geomorphology. http://dx.doi.org/10.1016/j.geomorph.2015.01.010

Photo courtesy of Andy Ritchie

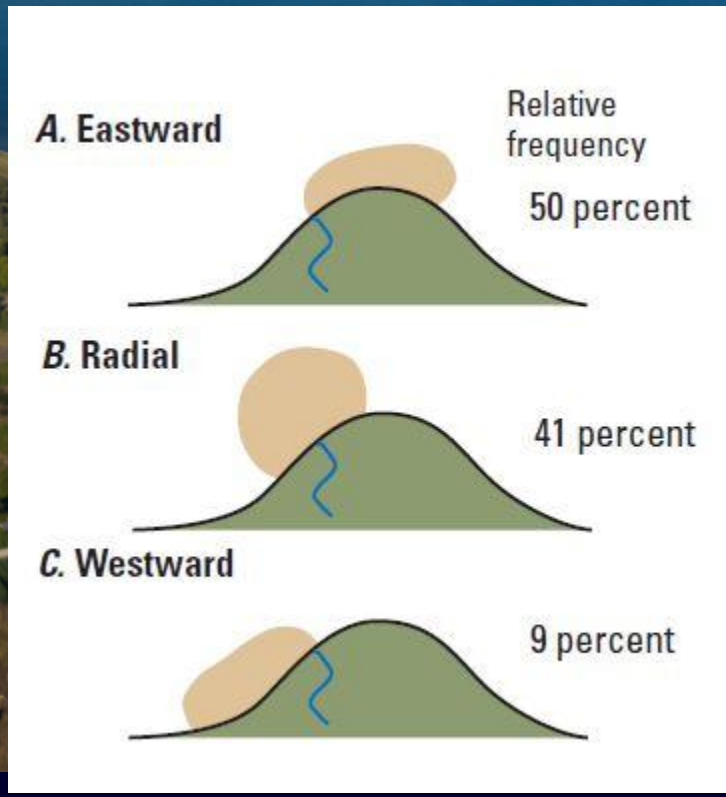
Photo courtesy of Andy Ritchie

Former Mills reservoir

Former Mills reservoir

Mouth of the Elwha River - nearshore

Photo: Matt Beirne, Lower Elwha Klallam Tribe



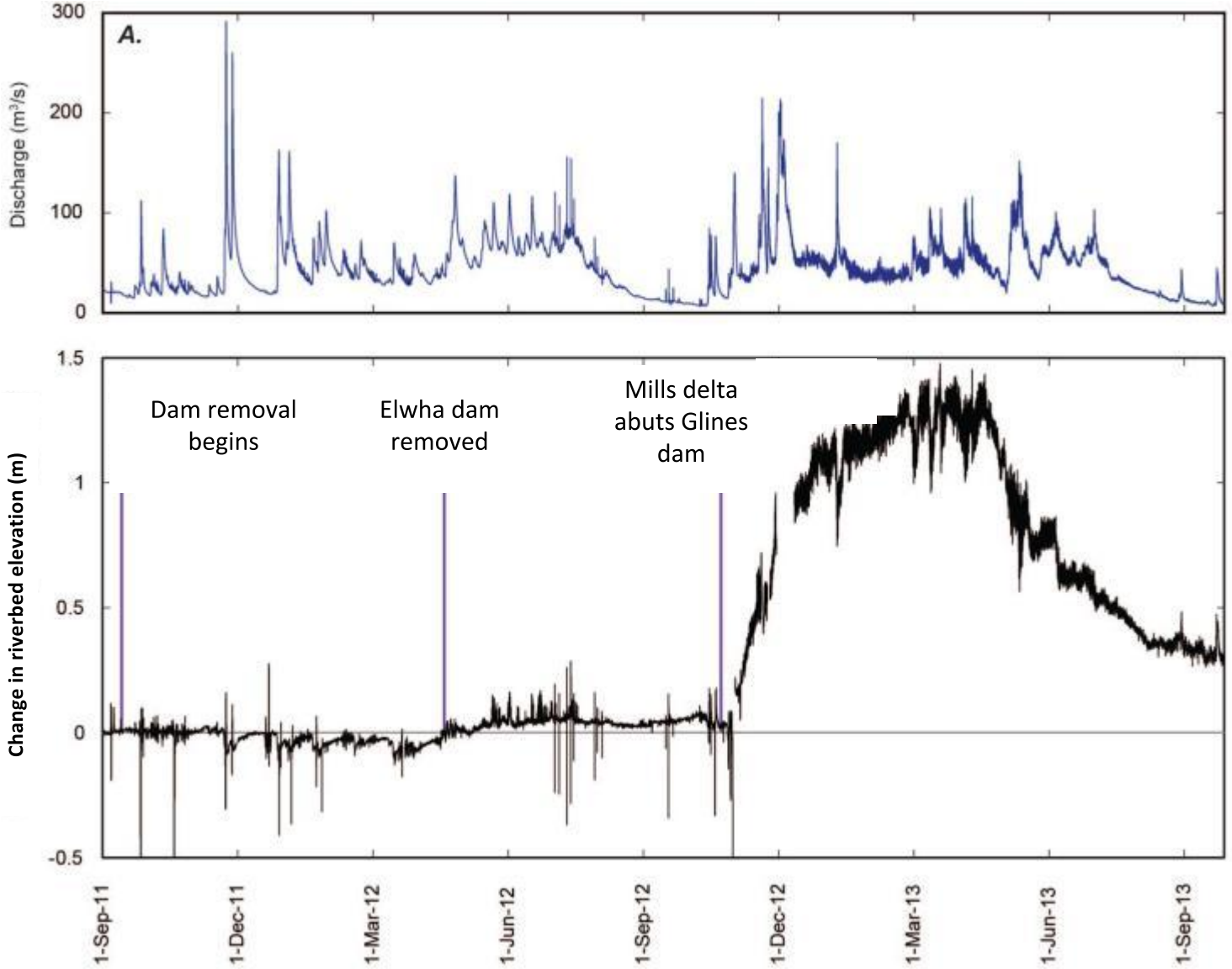
Warrick, J.A., and Stevens, A.W., 2011, A buoyant plume adjacent to a headland - observations of the Elwha River plume: Continental Shelf Research, v. 31, p. 85-97.

Mouth of the Elwha River - April 2012

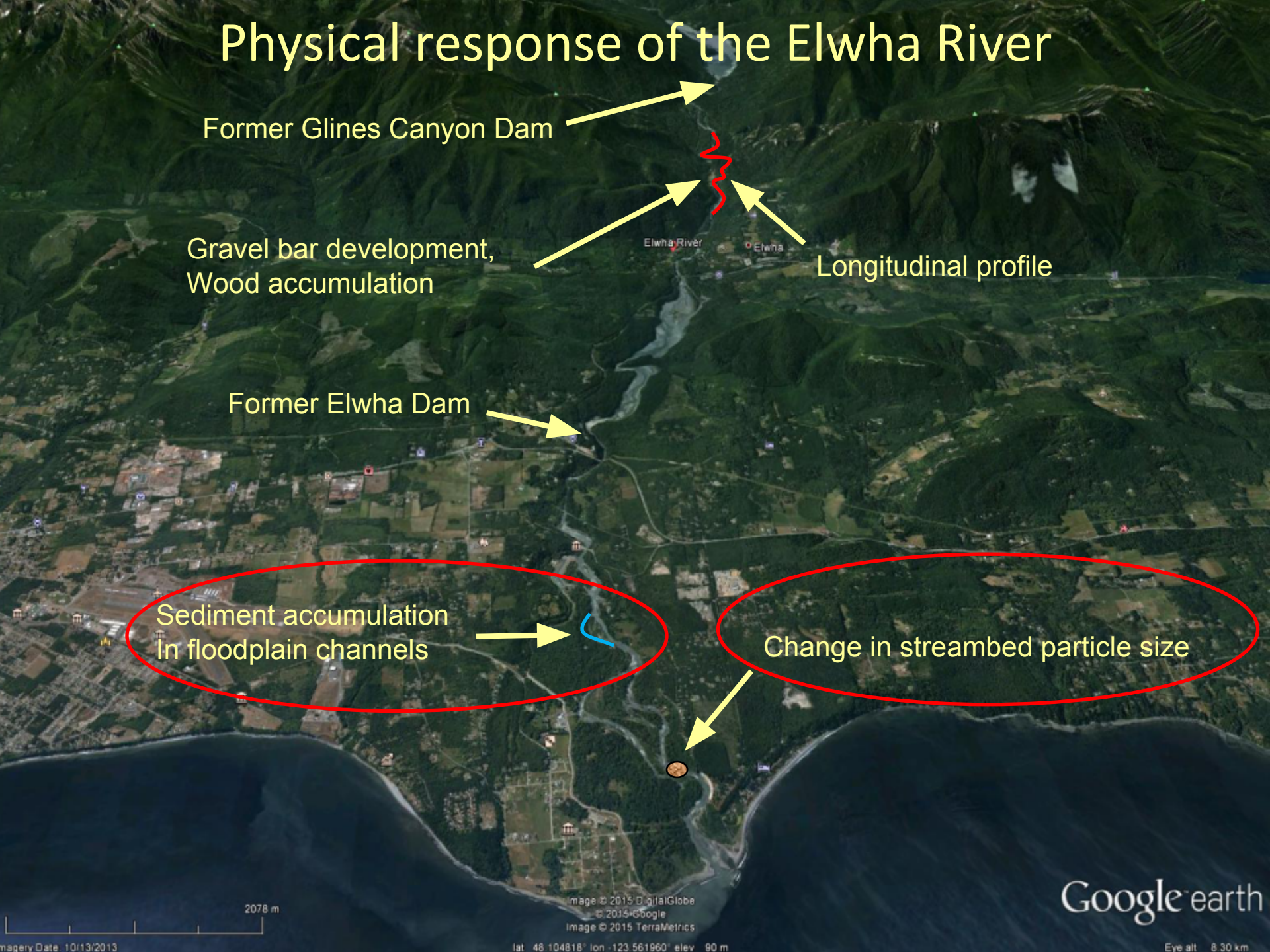
Much suspended sediment transported to the Strait of Juan De Fuca

Mouth of the Elwha River - April 2014

Changing sediment supply in the Elwha River



Magirl, C. S., Hilldale, R. C., Curran, C. A., Duda, J. J., Straub, T. D., Domanski, M., & Foreman, J. R. (2014). Large-scale dam removal on the Elwha River, Washington, USA: Fluvial sediment load. Geomorphology.


Physical response of the Elwha River
Former Glines Canyon Dam
Gravel bar development,
Wood accumulation
Longitudinal profile
Former Elwha Dam
Sediment accumulation
In floodplain channels
Change in streambed particle size
Elwha River
Elwha
2078 m
Image © 2015 DigitalGlobe
© 2015 Google
Image © 2015 TerraMetrics
Google earth

East, A. E., **Pess, G. R.**, Bountry, J. A., Magirl, C. S., Ritchie, A. C., Logan, J. B., & Shafroth, P. B. 2015. Large-scale dam removal on the Elwha River, Washington, USA: River channel and floodplain geomorphic change. Geomorphology, 228, 765-786.

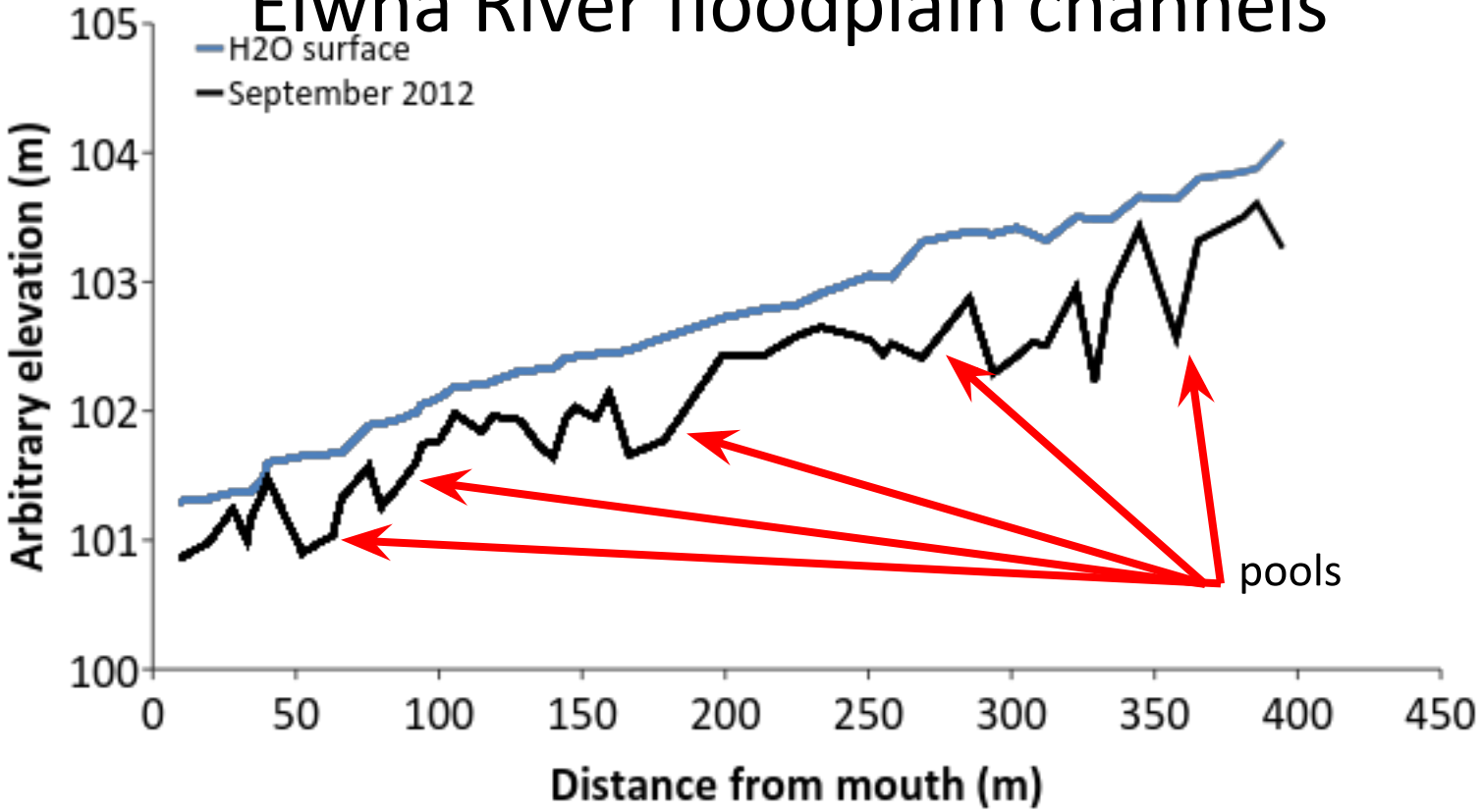
Physical response of the Elwha River floodplain channels

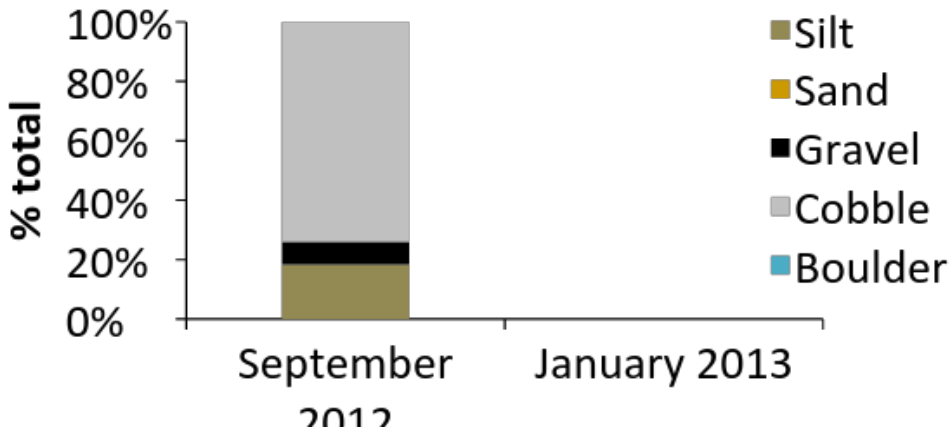
Boston Charley 1997

Boston Charley 2013

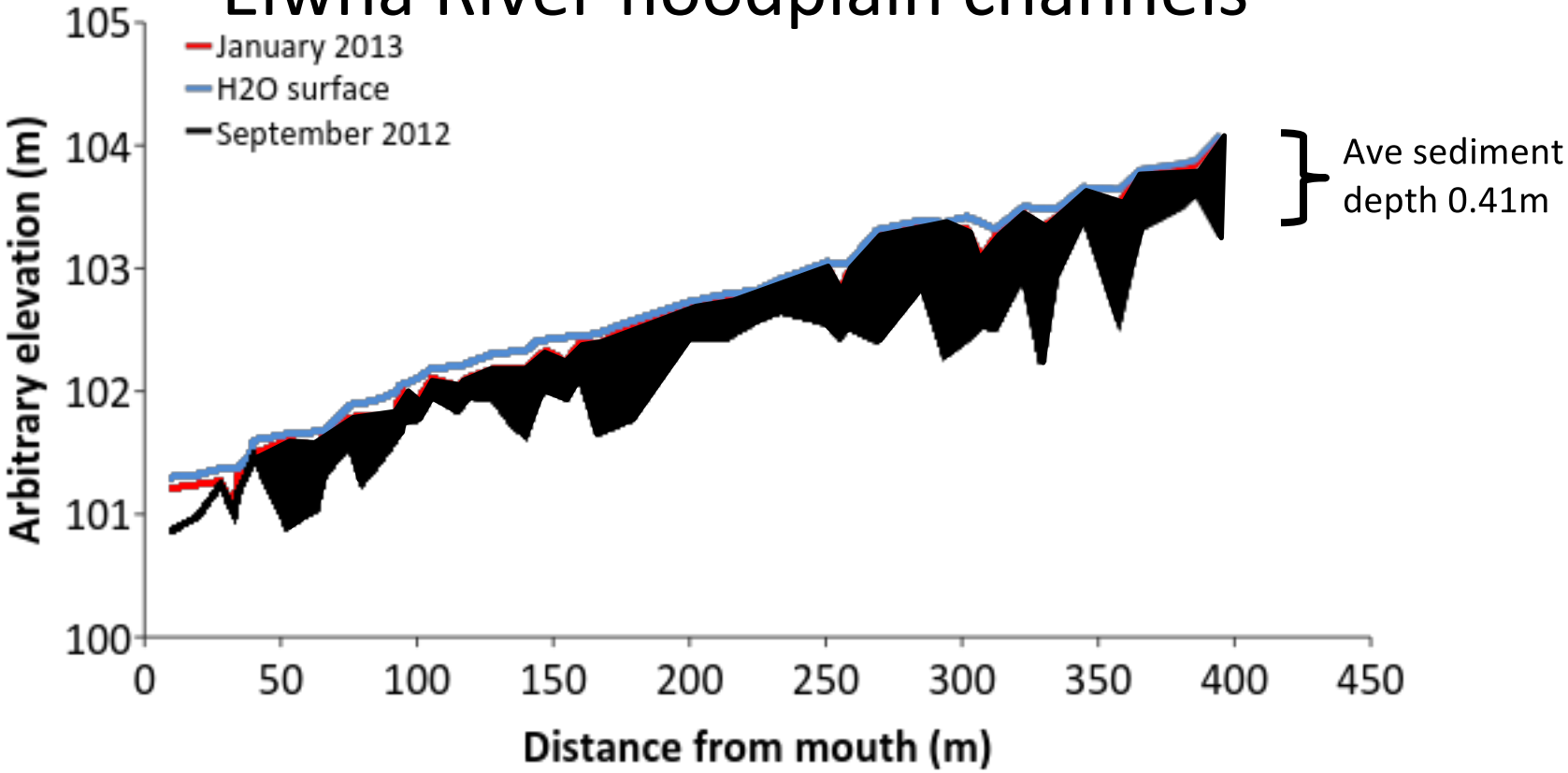
East, A. E., **Pess, G. R**., Bountry, J. A., Magirl, C. S., Ritchie, A. C., Logan, J. B., & Shafroth, P. B. 2015. Large-scale dam removal on the Elwha River, Washington, USA: River channel and floodplain geomorphic change. Geomorphology, 228, 765-786.

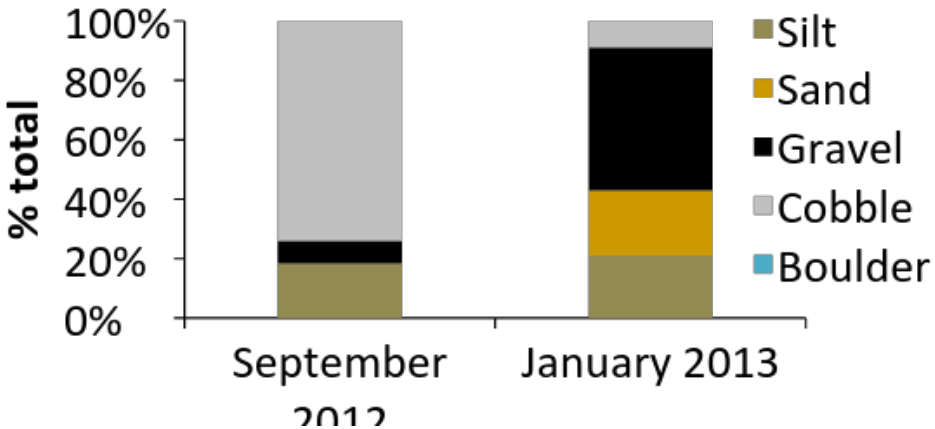
Physical response of the Elwha River floodplain channels





Physical response of the Elwha River floodplain channels

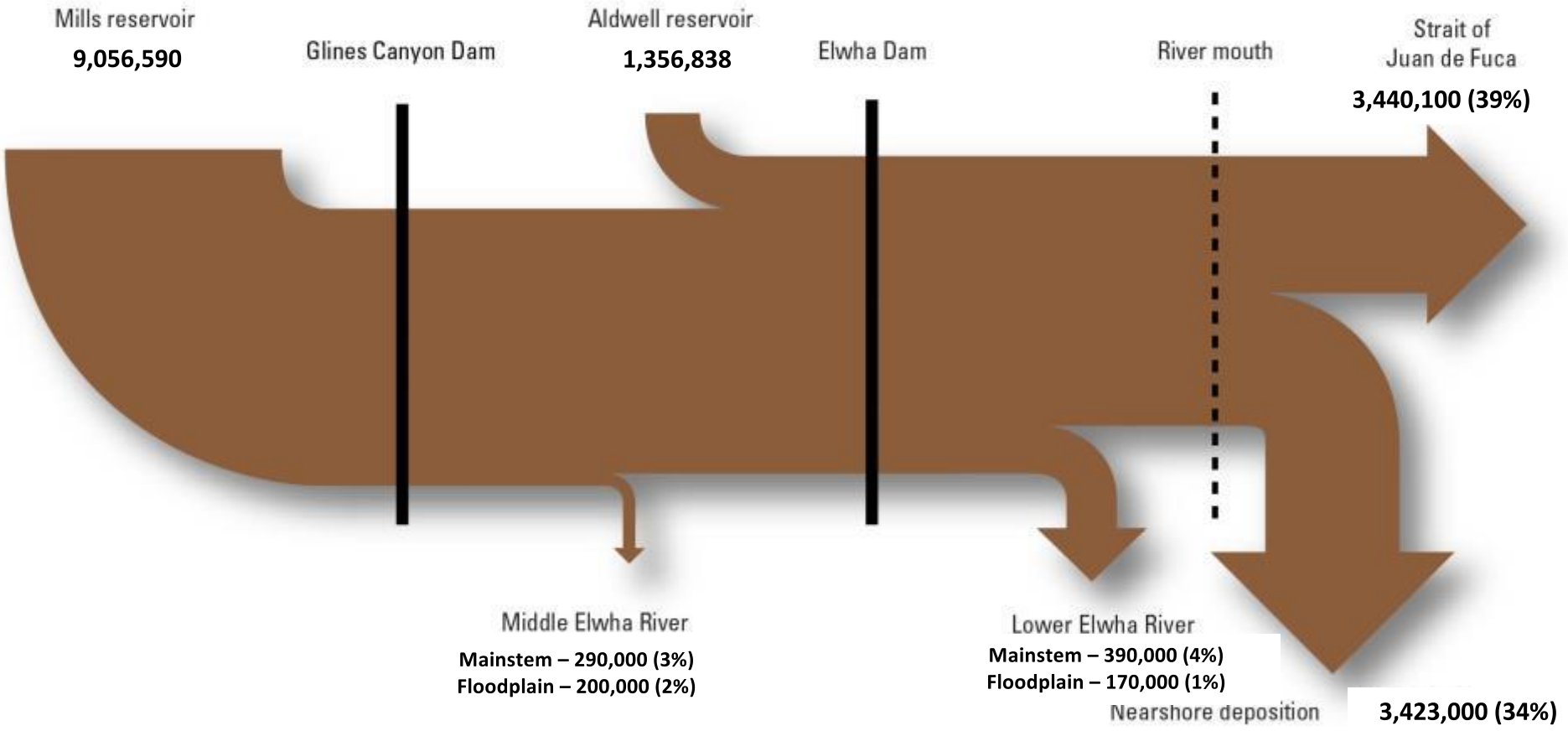




East, Amy E., et al. 2014. Large-scale dam removal on the Elwha River, Washington, USA: River channel and floodplain geomorphic change. Geomorphology
Gelfenbaum, Guy, et al. 2015. Large-scale dam removal on the Elwha River, Washington, USA: coastal geomorphic change. Geomorphology
Magirl, Christopher S., et al. 2015. Large-scale dam removal on the Elwha River, Washington, USA: Fluvial sediment load. Geomorphology
Warrick, J.A. et al. 2015. Large-scale dam removal on the Elwha River, Washington, USA: Source-to-sink sediment budget and synthesis. Geomorphology

Highway of Sediment

Sediment as of October 2013 in metric tonnes



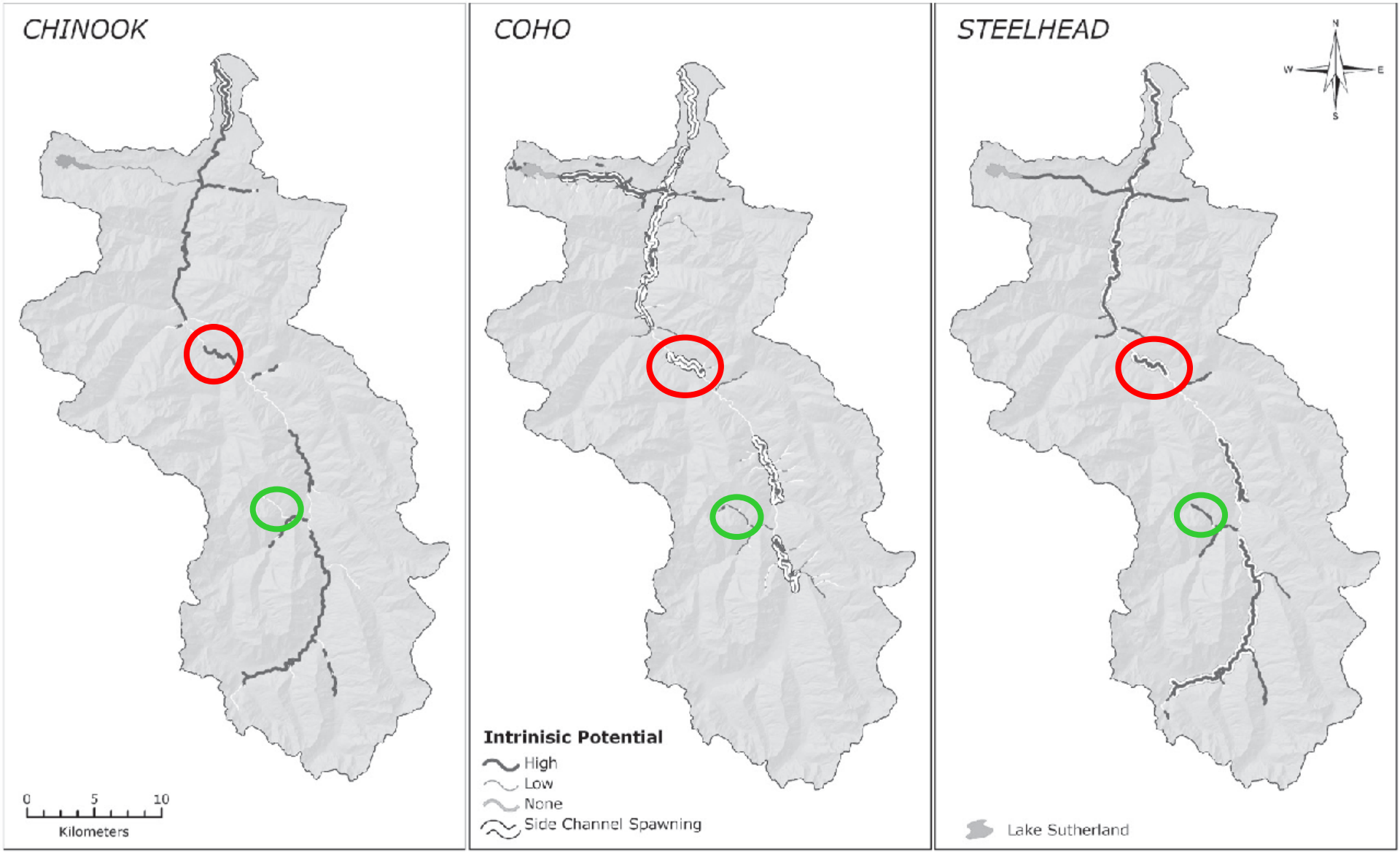
Data is provisional, subject to change
Unaccounted – 1,700,000 (~17%) metric tonnes

How will salmon populations change with the removal of the Elwha River dams?

- How long will it take salmon to colonize & establish spawning populations?
- What habitats & locations will different salmon species colonize?
- How many more salmon will there be?
- How will we measure change?
- What are some of the results to date?

What habitats and locations will different salmon species colonize in the Elwha River?

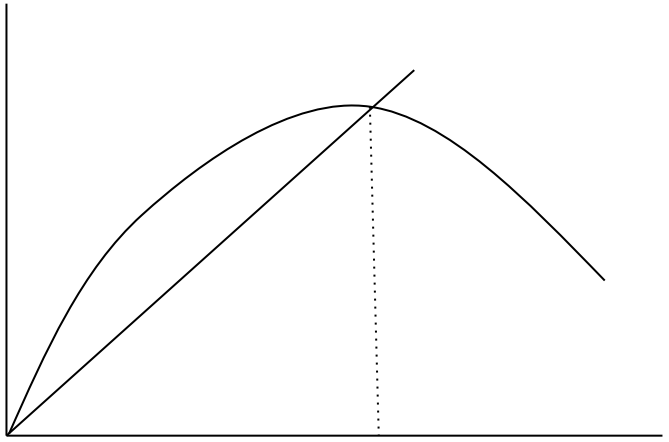
Pess, G. R., M. McHenry, **T. J. Beechie, J. R. Davies**. 2008. Biological impacts of the Elwha River dams and potential salmonid responses to dam removal. Northwest Science, 82(sp1):72-90.



How many more salmon will there be in the Elwha River?

$$S_{rep} = \chi \hat{b} * e^{\ln \hat{a} + (\frac{\hat{\sigma}^2}{2})}$$

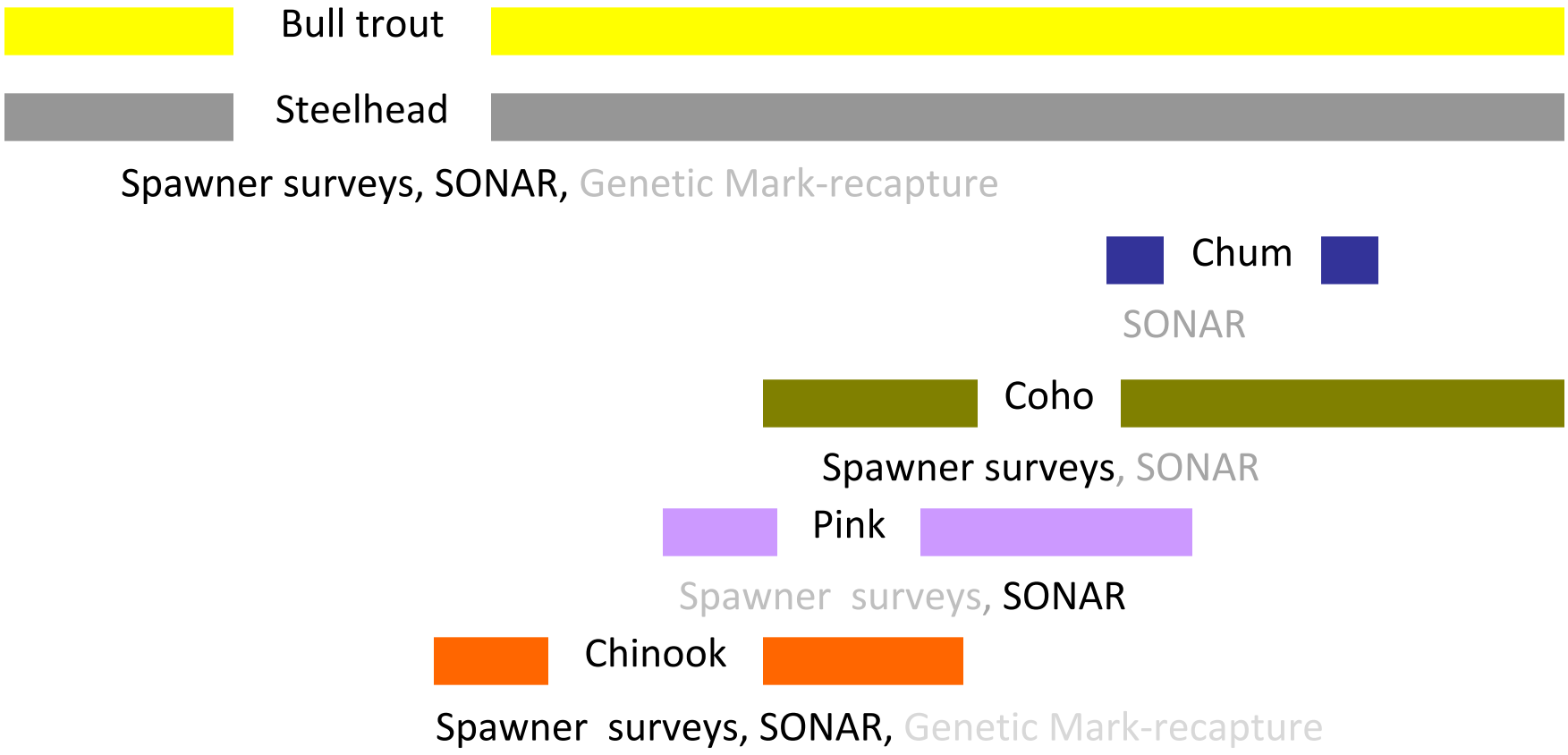
χ = drainage area (km^2)



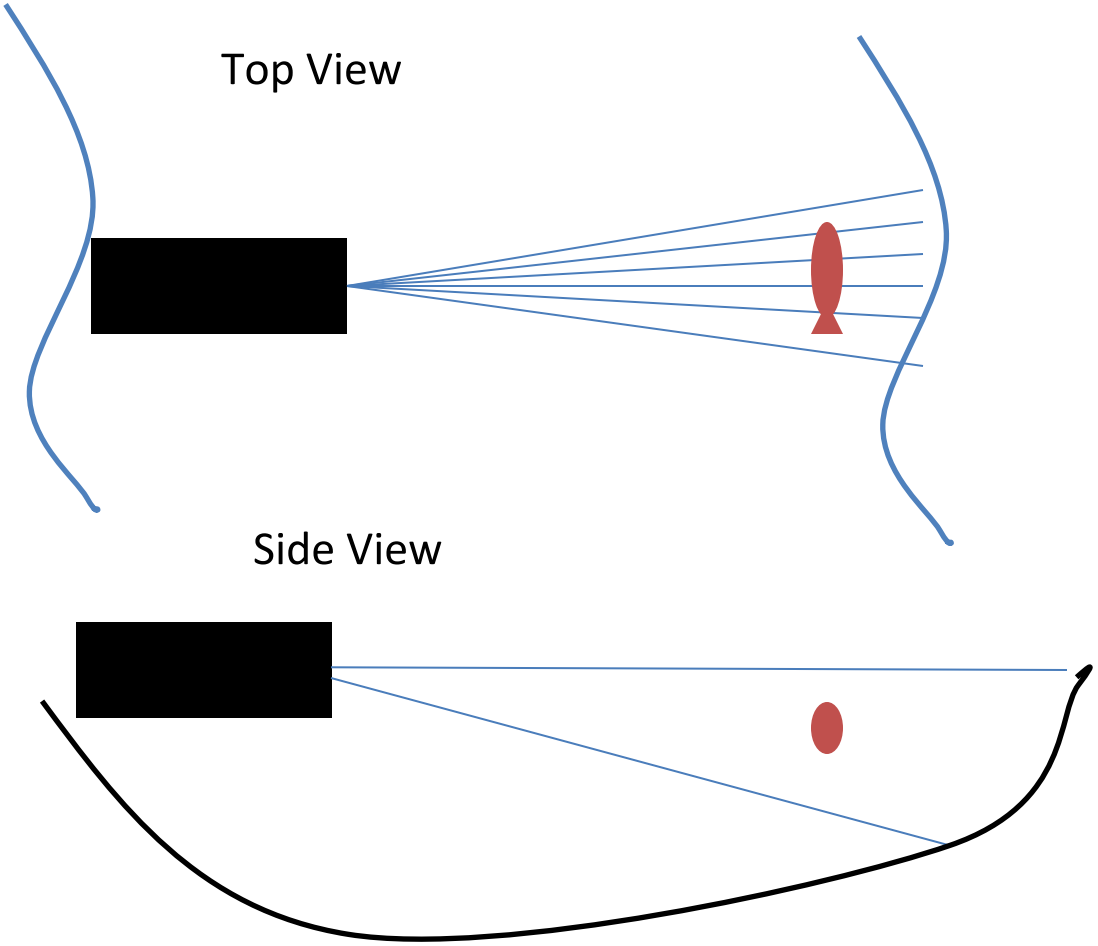
Elwha Chinook Estimate	Equilibruim Population Size
Stream type	**4,589**
Ocean type	**10,099**

Peters, R.J., J.J. Duda, **G.R. Pess**, M. Zimmerman, P. Crain, Z. Hughes, A. Wilson, **M.C. Liermann**, **S.A. Morley**, **J.R. McMillan, K. Denton**, D. Morrill, and K. Warheit. 2014. Guidelines for monitoring and adaptively managing restoration of Chinook salmon and Steelhead on the Elwha River . USFWS. 101 pages. Lacey, WA

How will we measure change for adult salmon in the Elwha River?

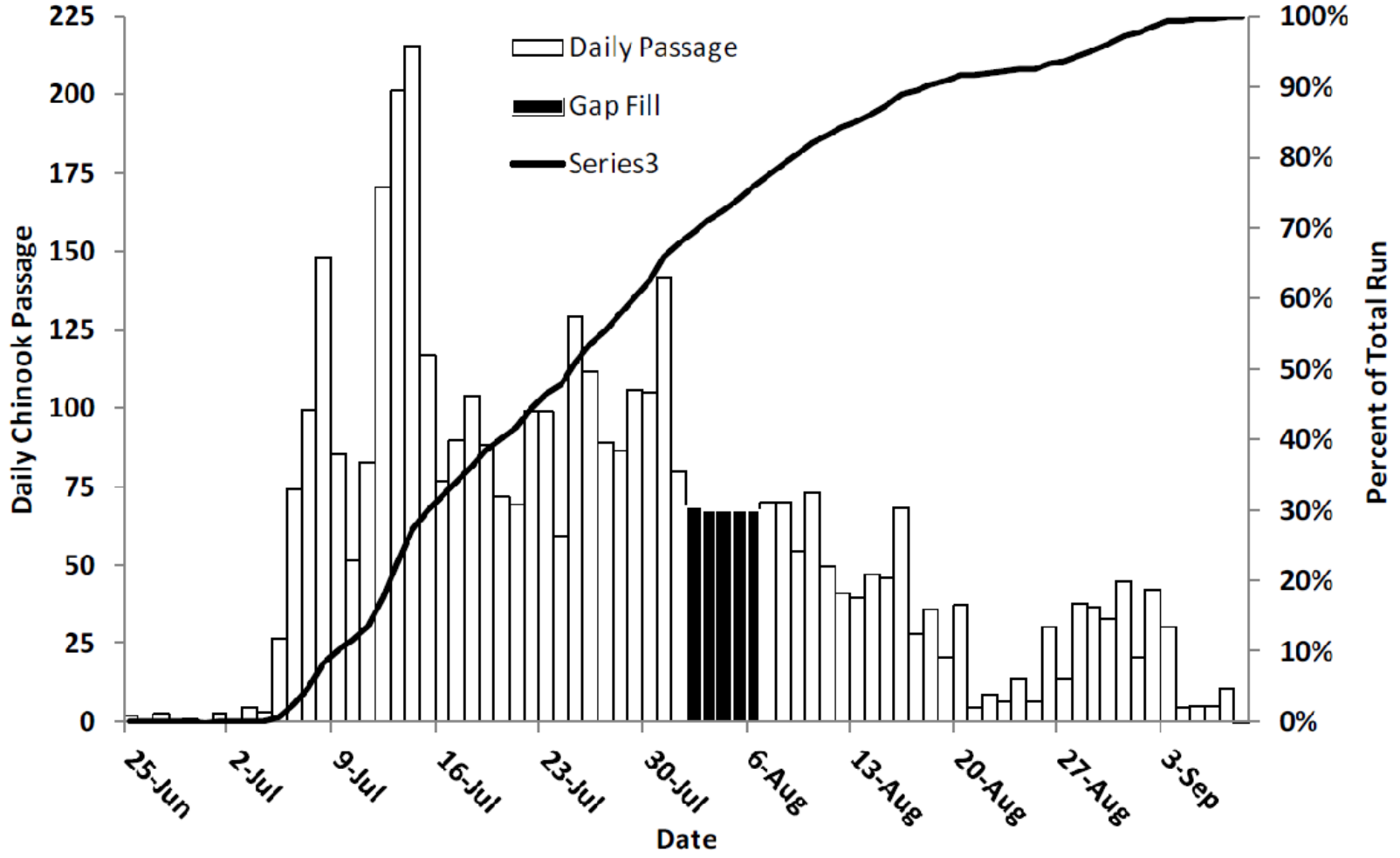


What is SONAR?



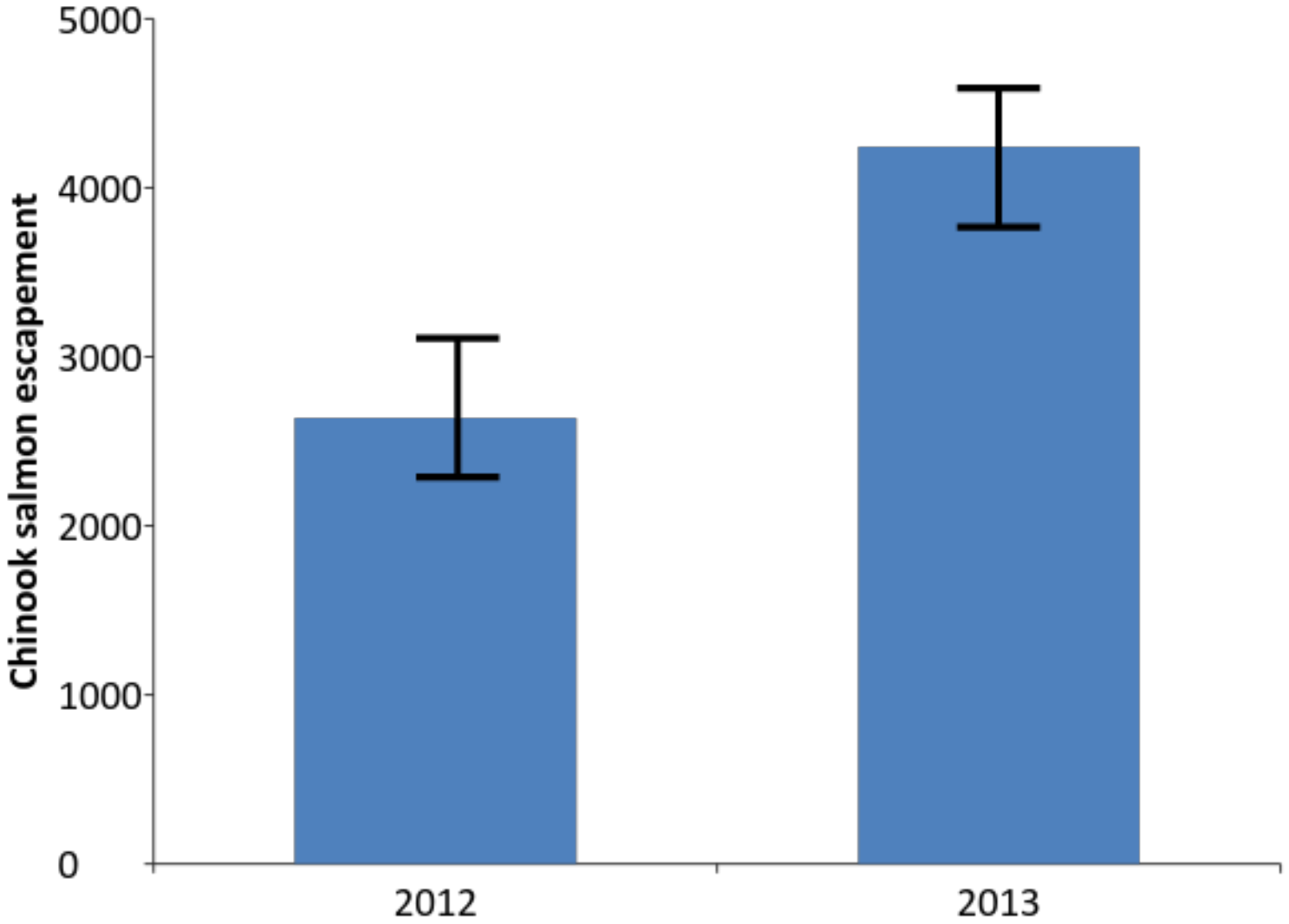
Elwha River SONAR location to enumerate adult Chinook salmon and Steelhead

2013 Elwha River Chinook salmon daily fish passage at SONAR sites



Denton, K., R. Moses, **E. Ward, M. Liermann, O. Stefankiv**, W. Wells, and **G. Pess**. 2014. 2014 Elwha River Chinook escapement based in DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park by the LEKT. Port Angeles, WA.

Estimated Elwha River Chinook salmon escapement using SONAR



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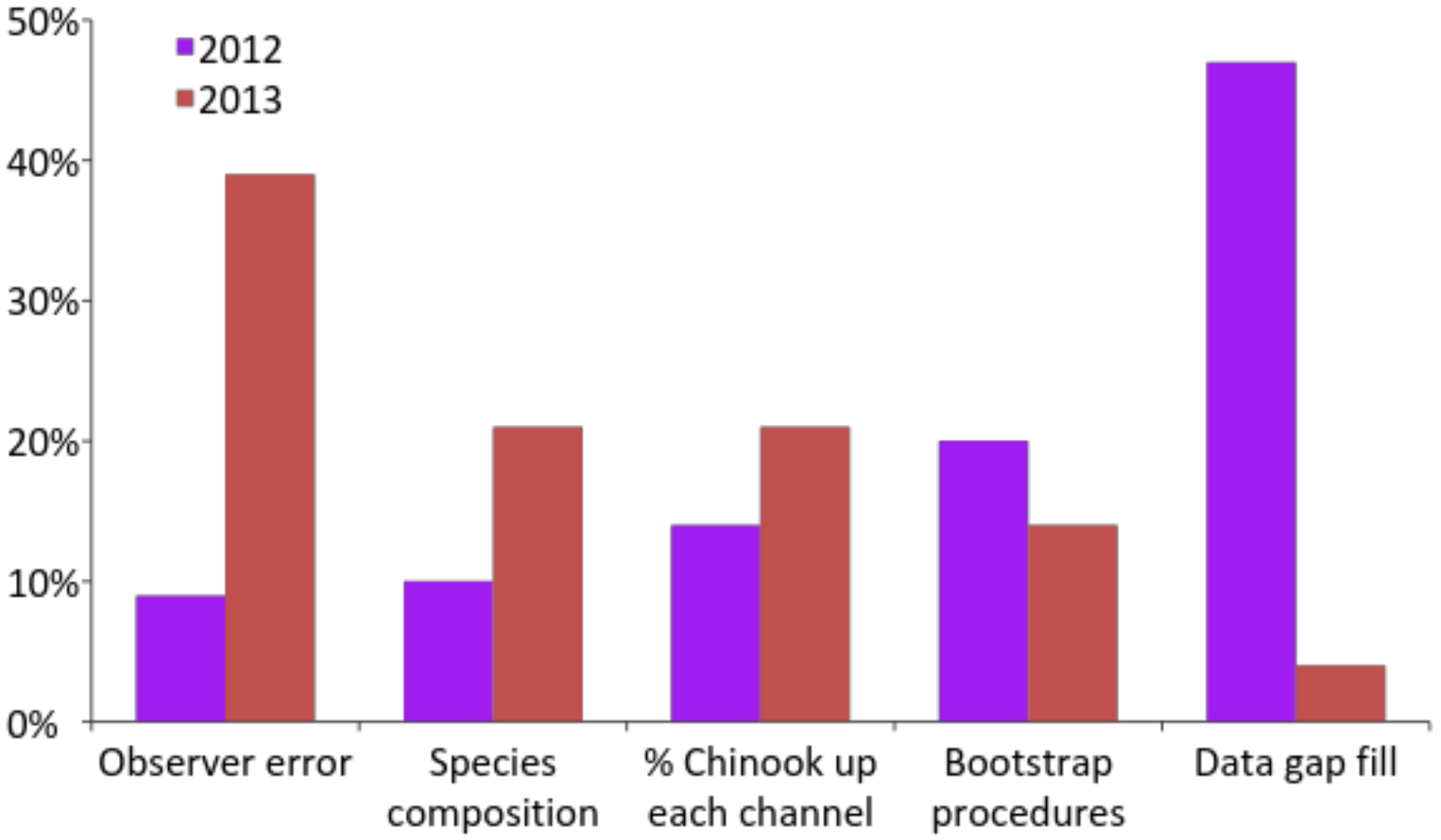
Sources of uncertainty associated with the 2012 & 2013 Elwha River Chinook salmon escapement



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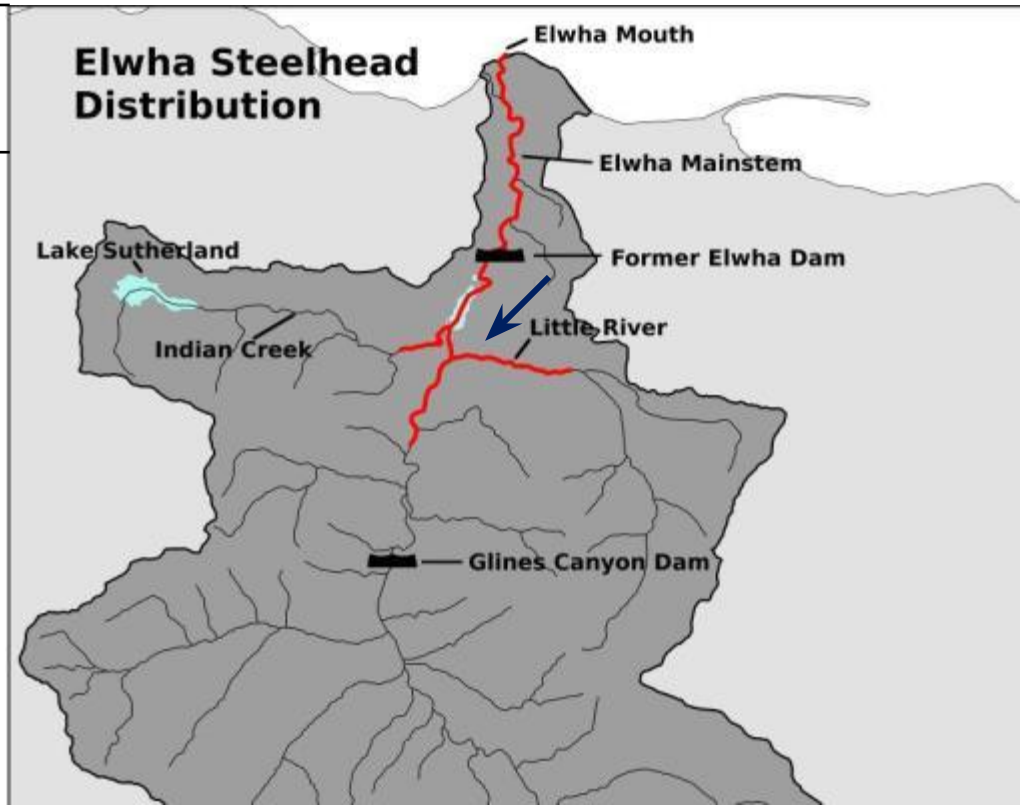
Denton, K., M. McHenry, R. Moses, **M. Liermann,** and **G. Pess**. 2013. 2013 Elwha River Chinook escapement based in DIDSON/ARIS multi-beam SONAR data. Report to Olympic National Park by the LEKT. Port Angeles, WA.

Salmon recolonization in the middle Elwha River

- 2011-2014 Relocation
  - Hatchery & wild adult coho salmon
  - Wild steelhead
- 2011-2014 Natural colonization
  - Steelhead
  - Pink salmon
  - Chinook salmon
  - Coho salmon
- Life stage specific distribution & abundance
  - Redd counts
  - Snorkel surveys
  - Summer parr estimates
  - Smolt estimates

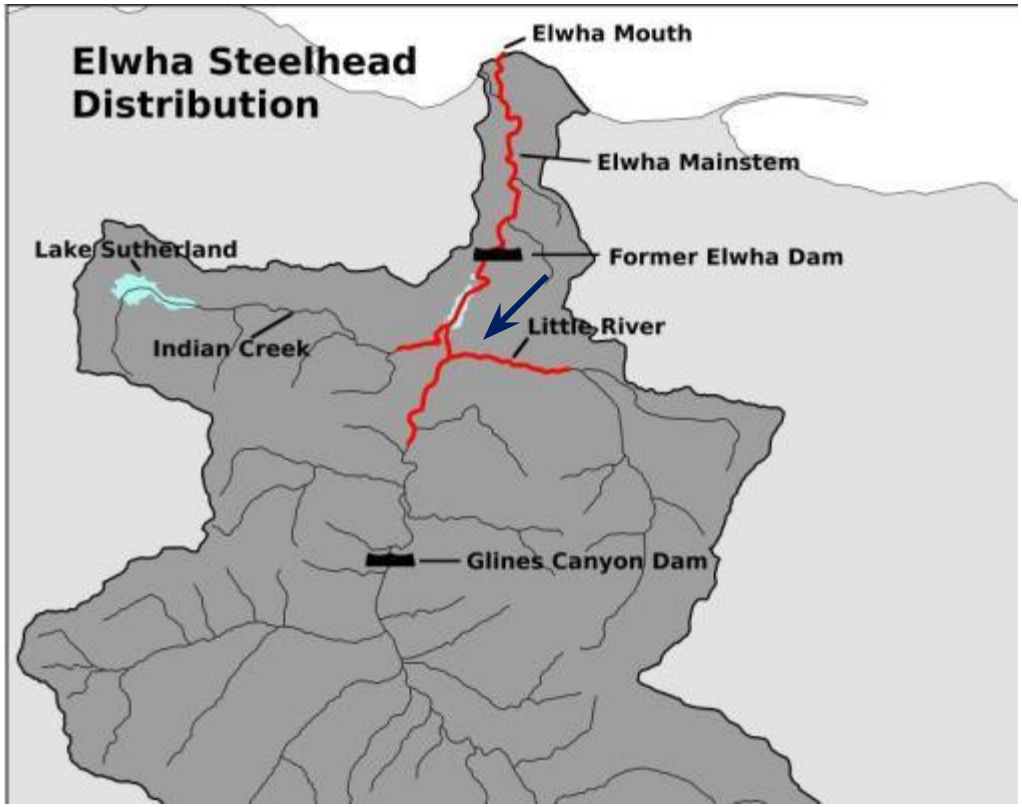
Relocation of adult steelhead in the middle Elwha River - Spring of 2012

Release Location	Male Stlhd	Female Stlhd	Rainbow trout
Little River	11	39	15

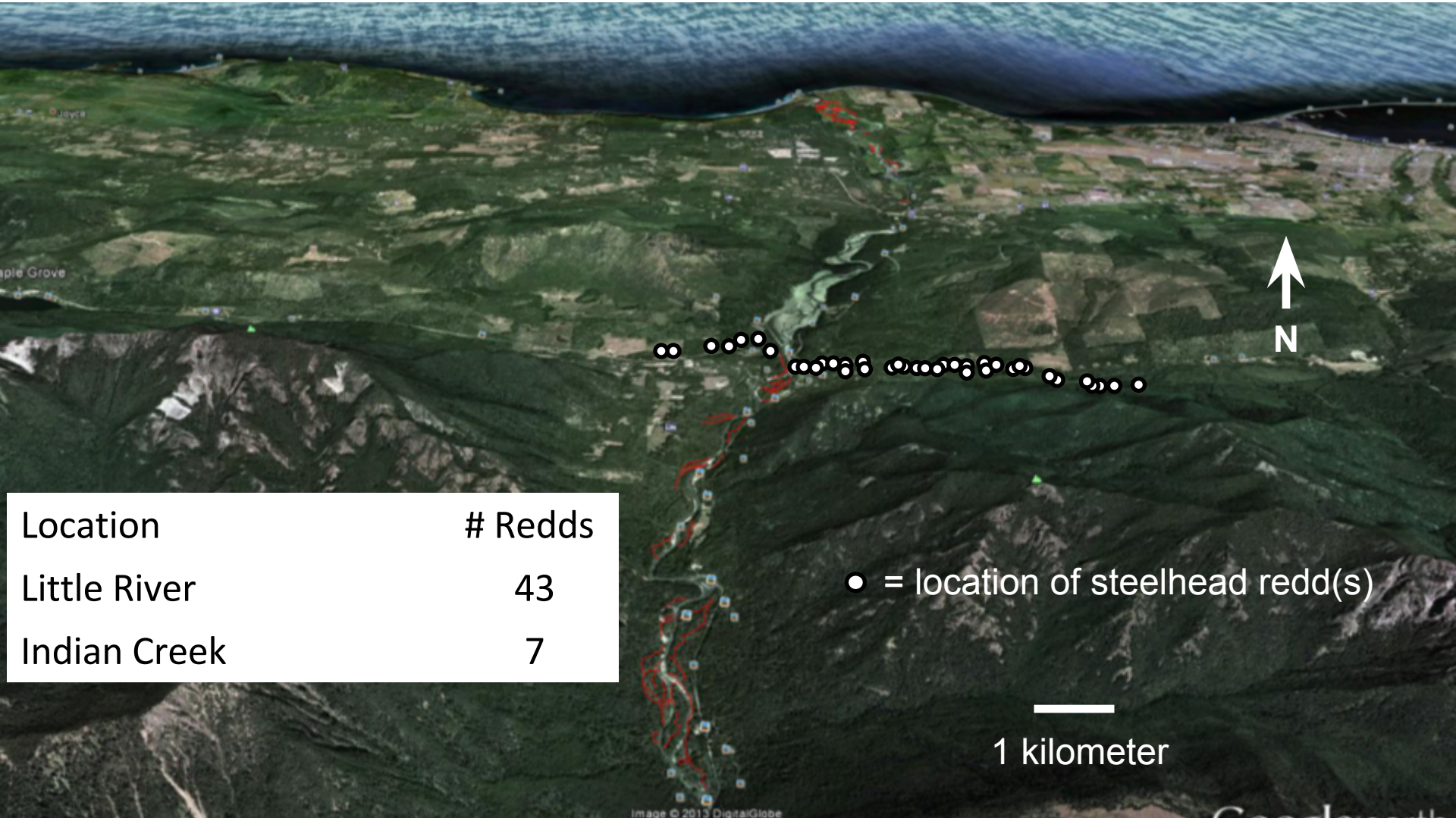


Natural colonization of adult steelhead in the middle Elwha River - 2011 to 2013

Natural colonizers	Male Stlhd	Female Stlhd
Little River	5	3
Indian Creek	6	4



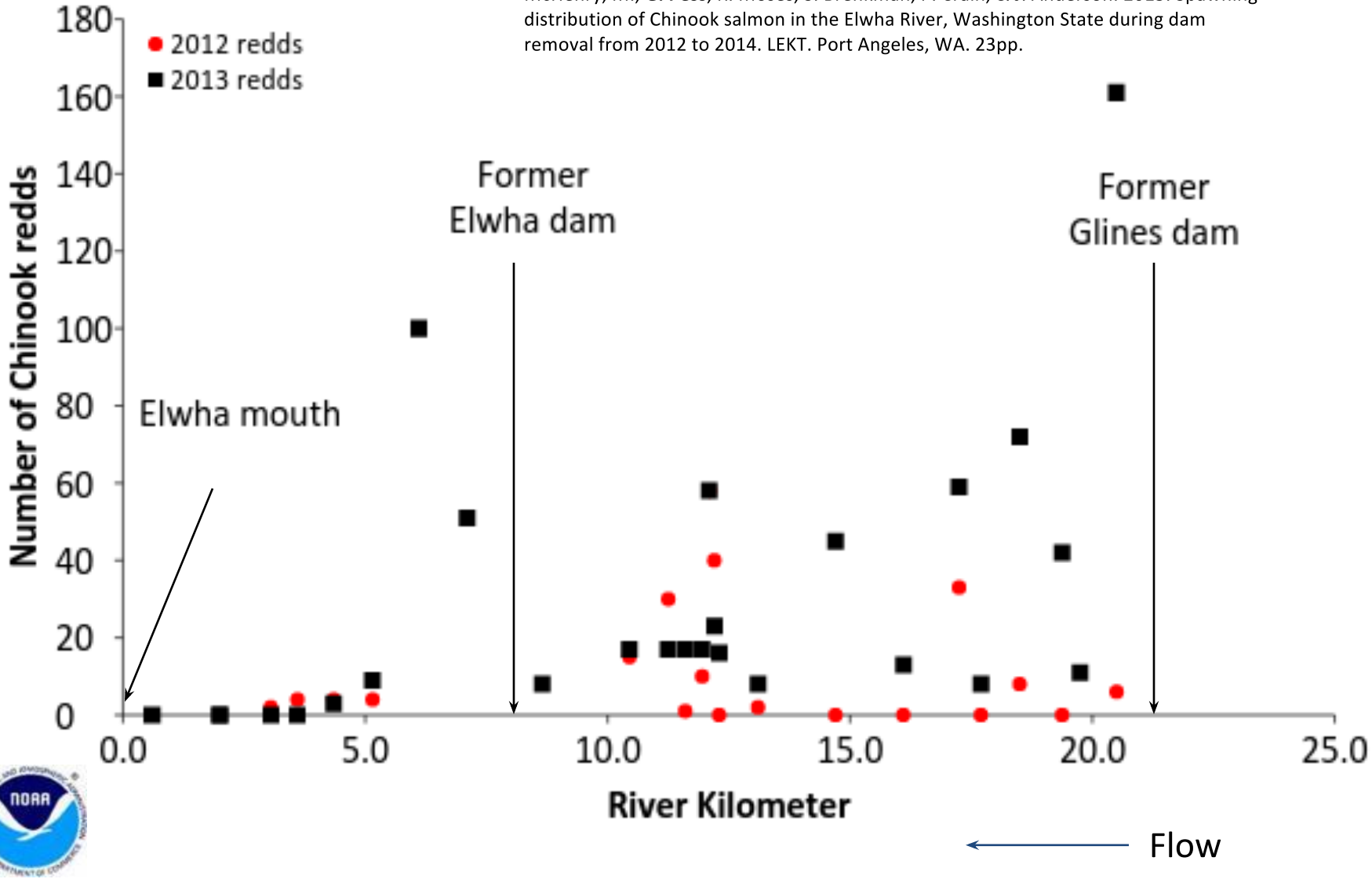
Steelhead redds in the middle Elwha River – Spring & summer of 2012



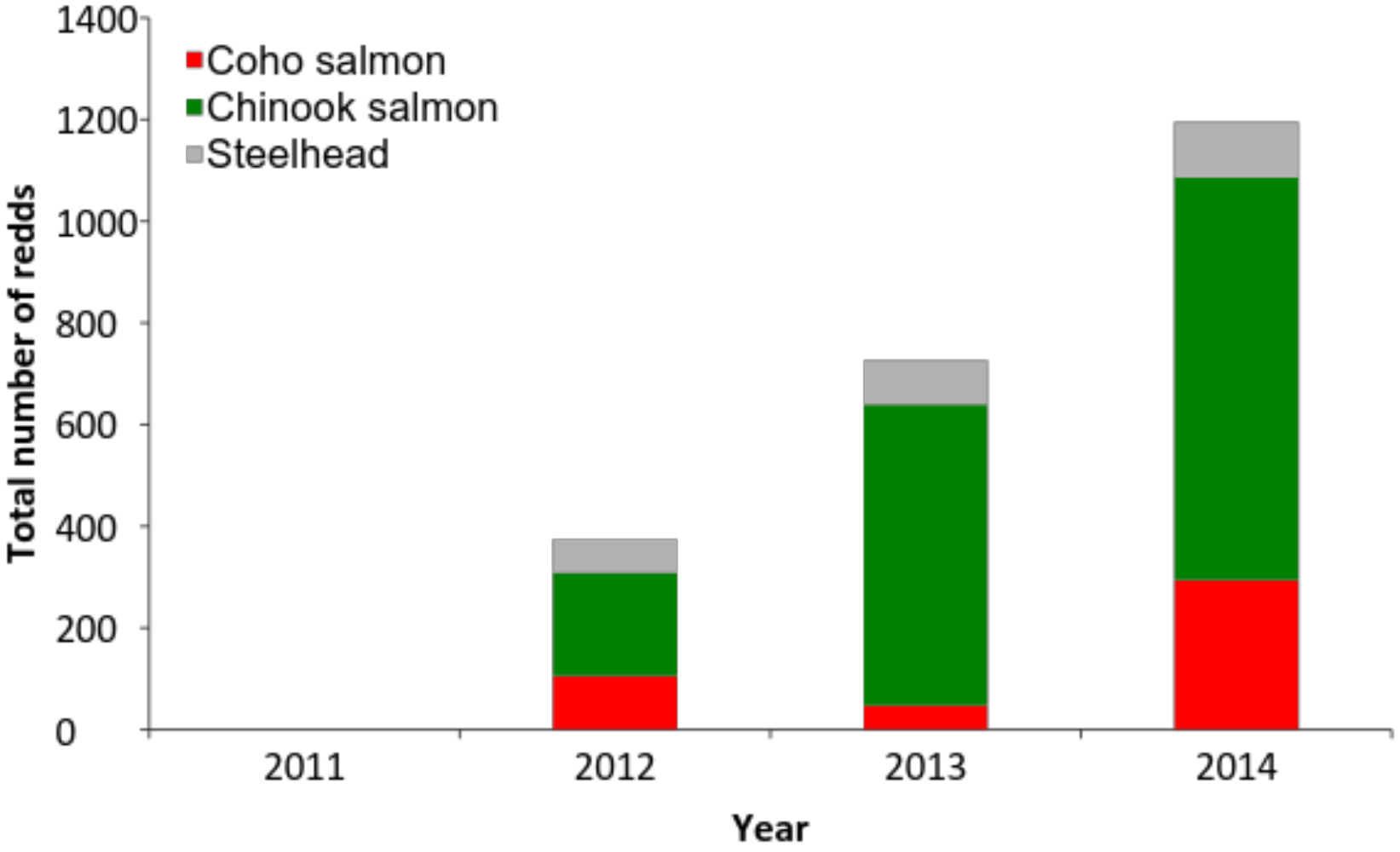
Location	# Redds
Little River	43
Indian Creek	7

Natural recolonization of Chinook salmon in the middle Elwha River – 2012 & 2013

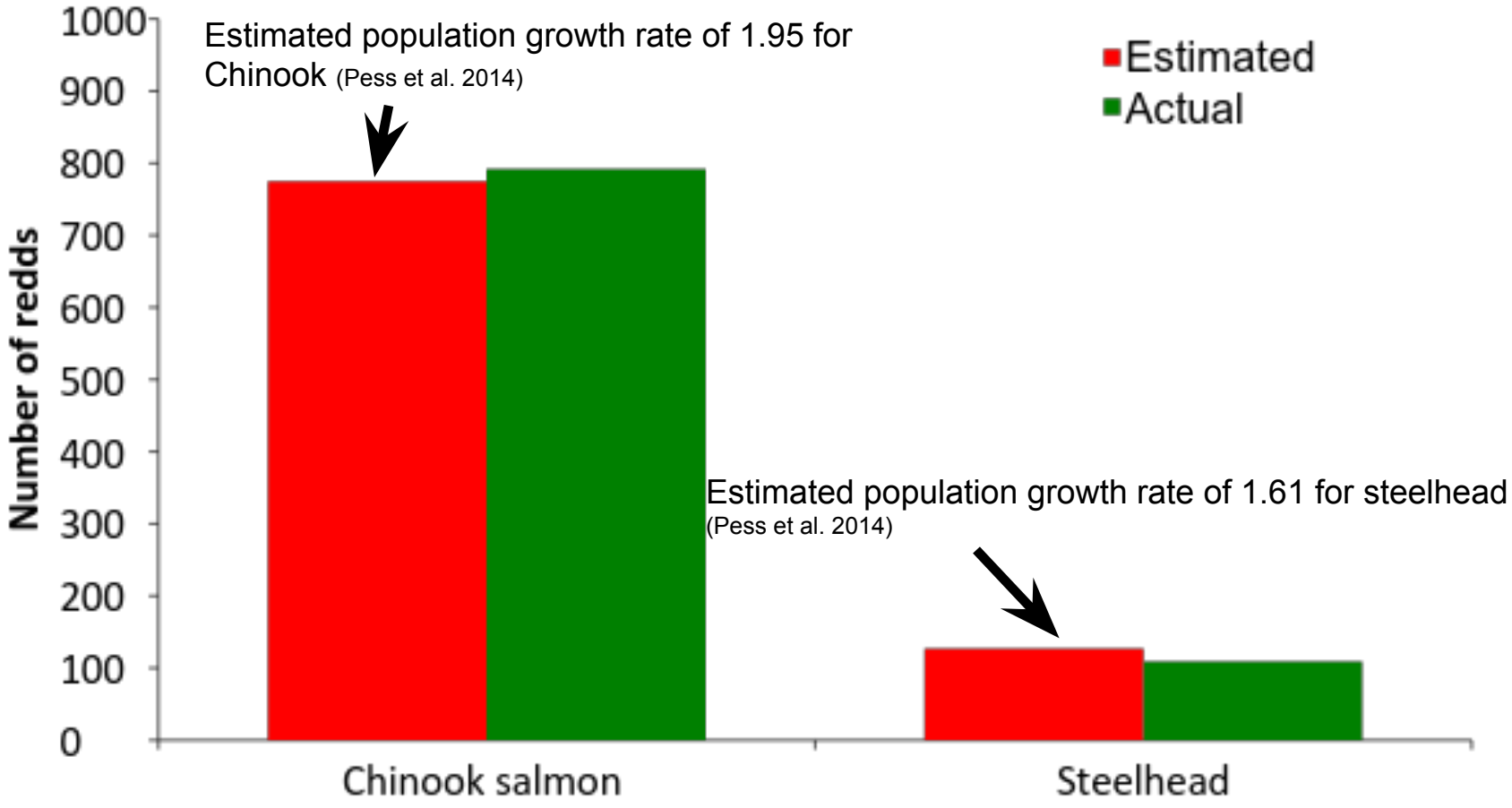
McHenry, M., **G. Pess**, R. Moses, S. Brenkman, P. Crain, & J. Anderson. 2015. Spawning distribution of Chinook salmon in the Elwha River, Washington State during dam removal from 2012 to 2014. LEKT. Port Angeles, WA. 23pp.



Total number of redds in the middle Elwha River - 2012 to 2014

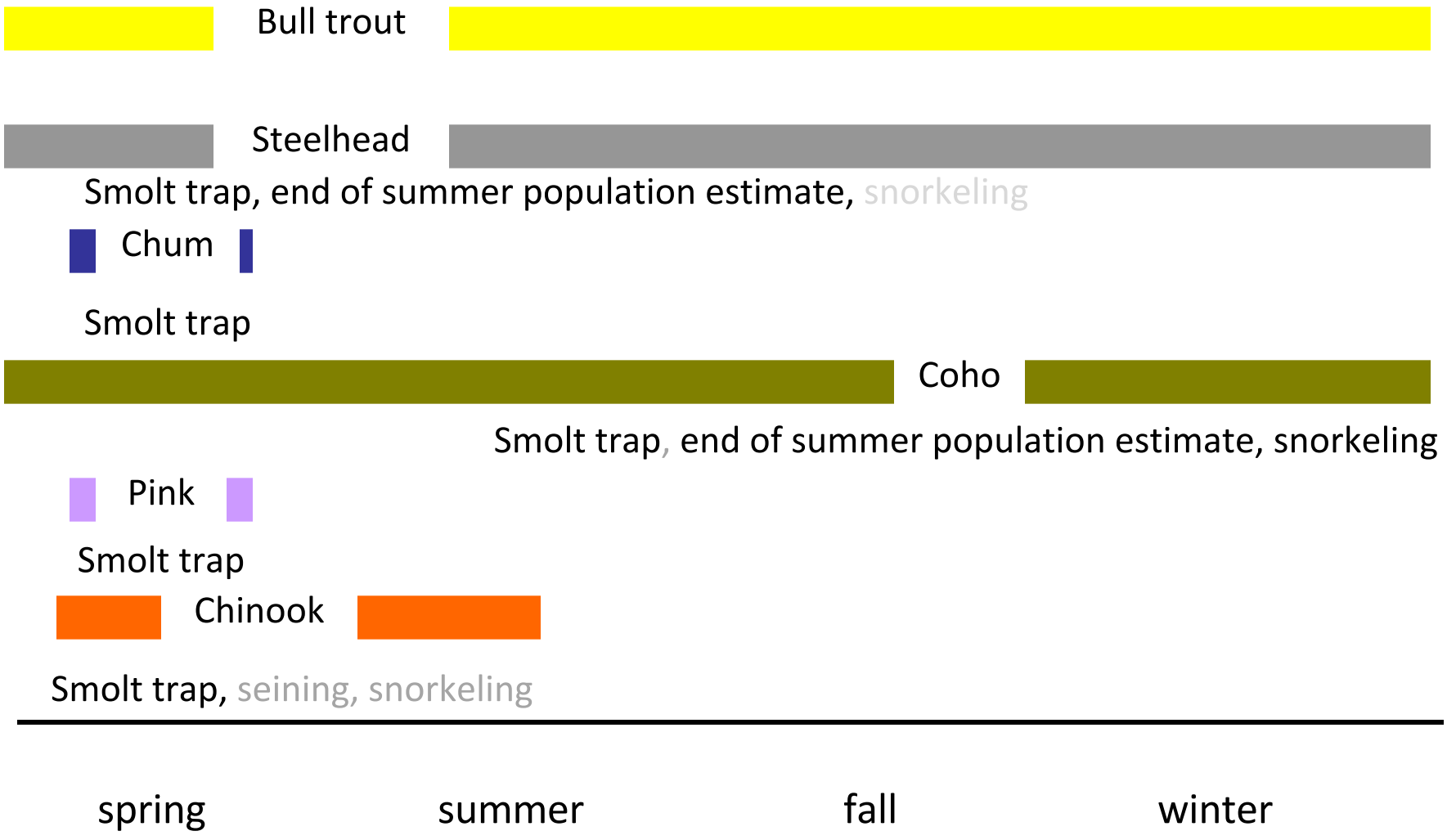


2014 actual & estimated Chinook salmon and steelhead redds in the middle Elwha River

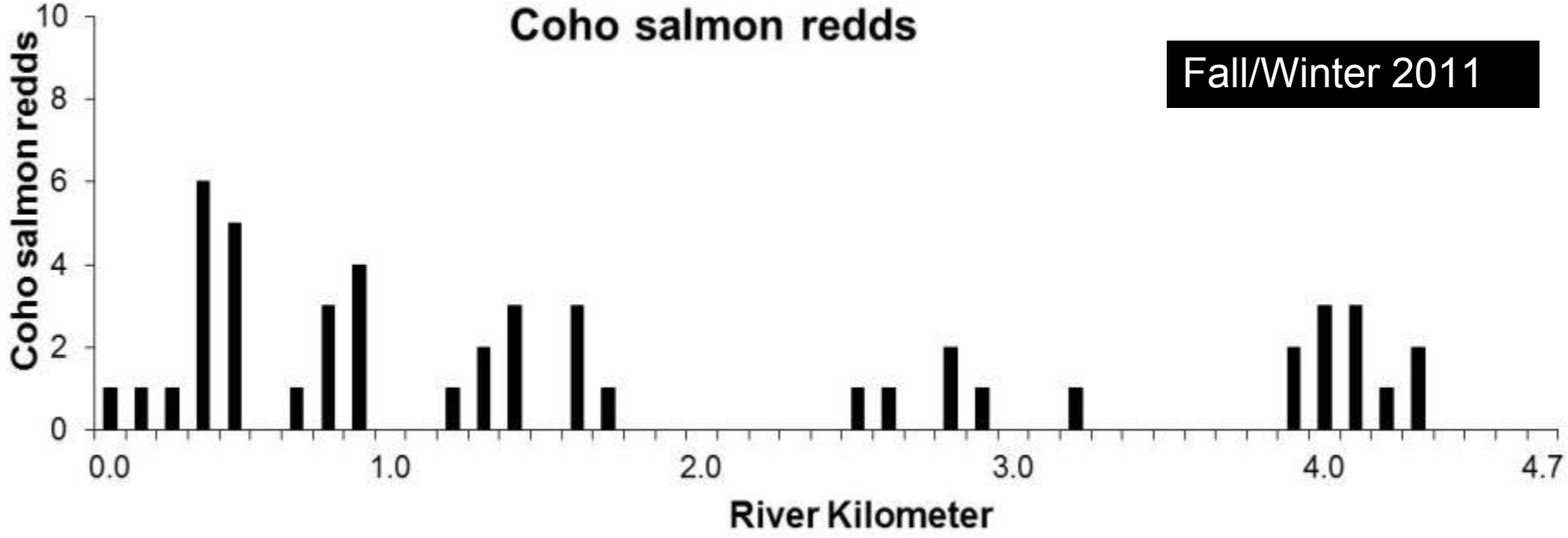


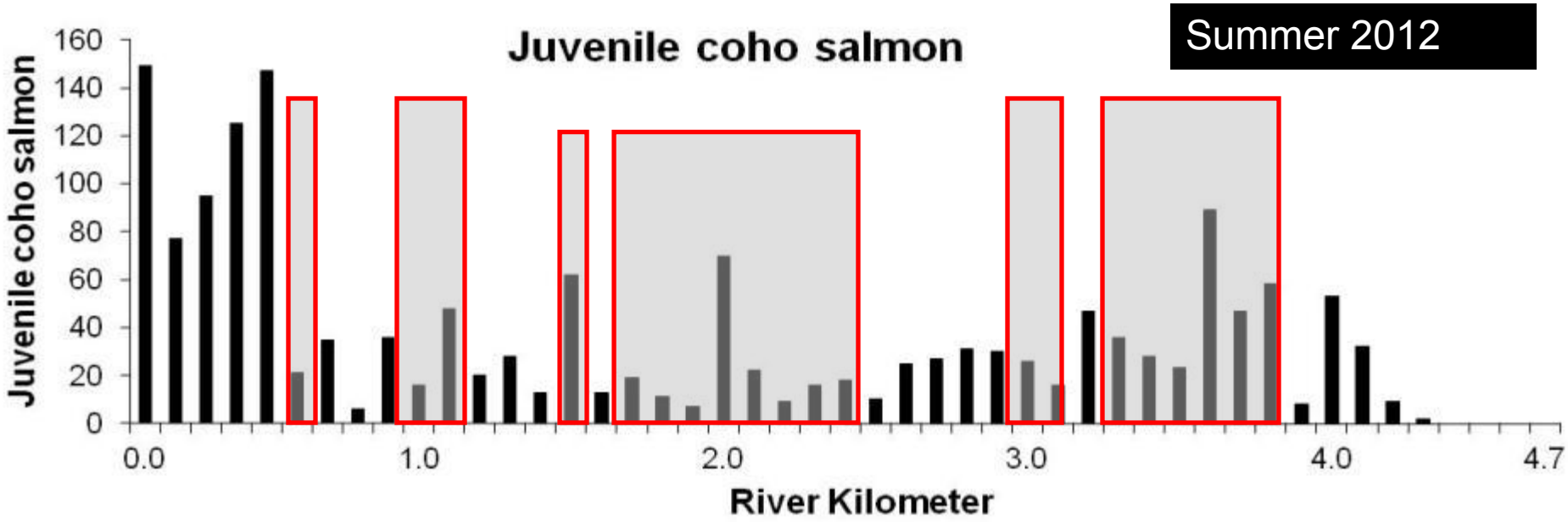
Pess, G. R., Quinn, T. P., Gephard, S. R., & Saunders, R. (2014). Re-colonization of Atlantic and Pacific rivers by anadromous fishes: linkages between life history and the benefits of barrier removal. Reviews in Fish Biology and Fisheries, 24(3), 881-900.

How will we measure change for juvenile salmon in the Elwha River?

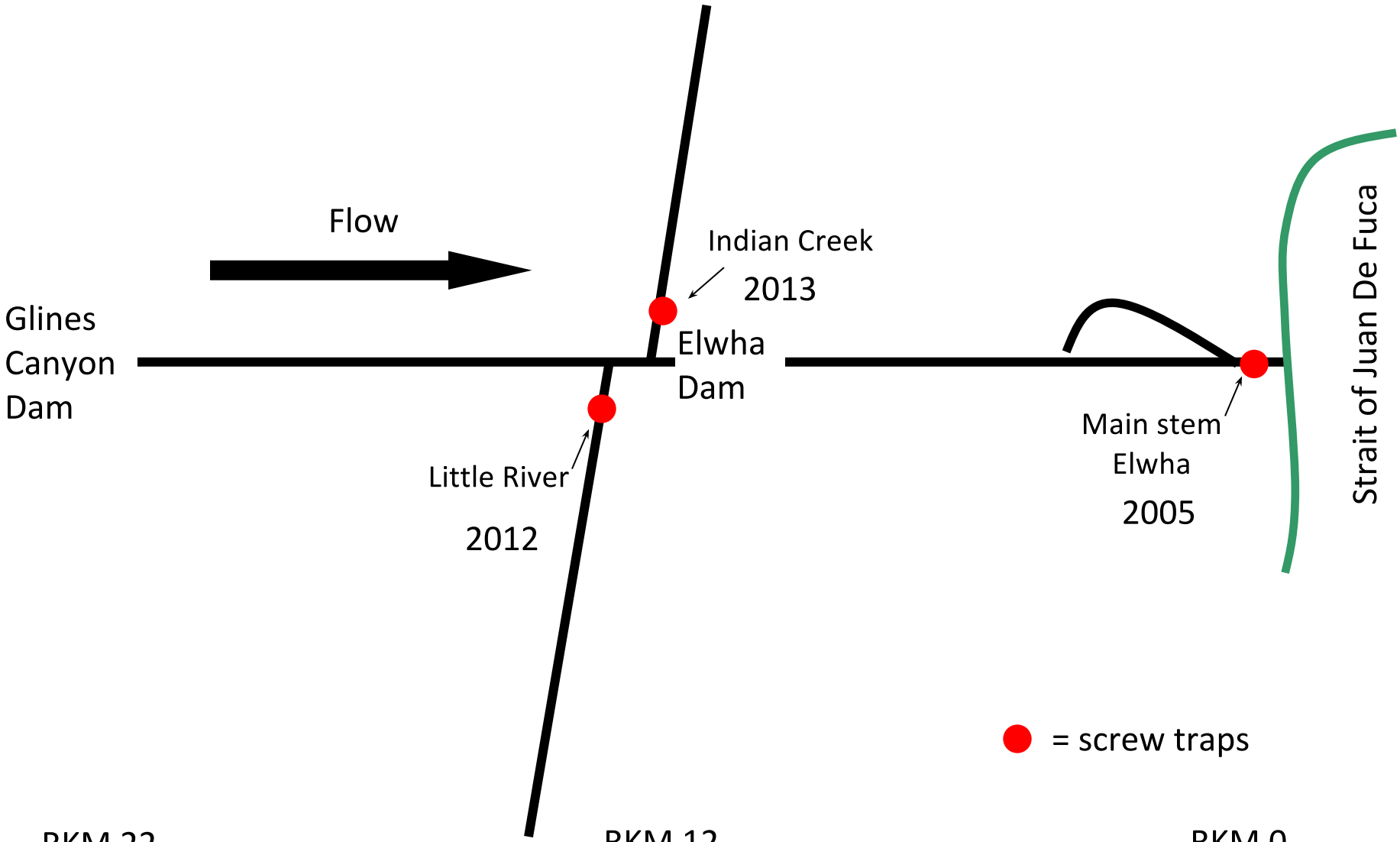


Little River coho salmon redd & juvenile snorkel surveys

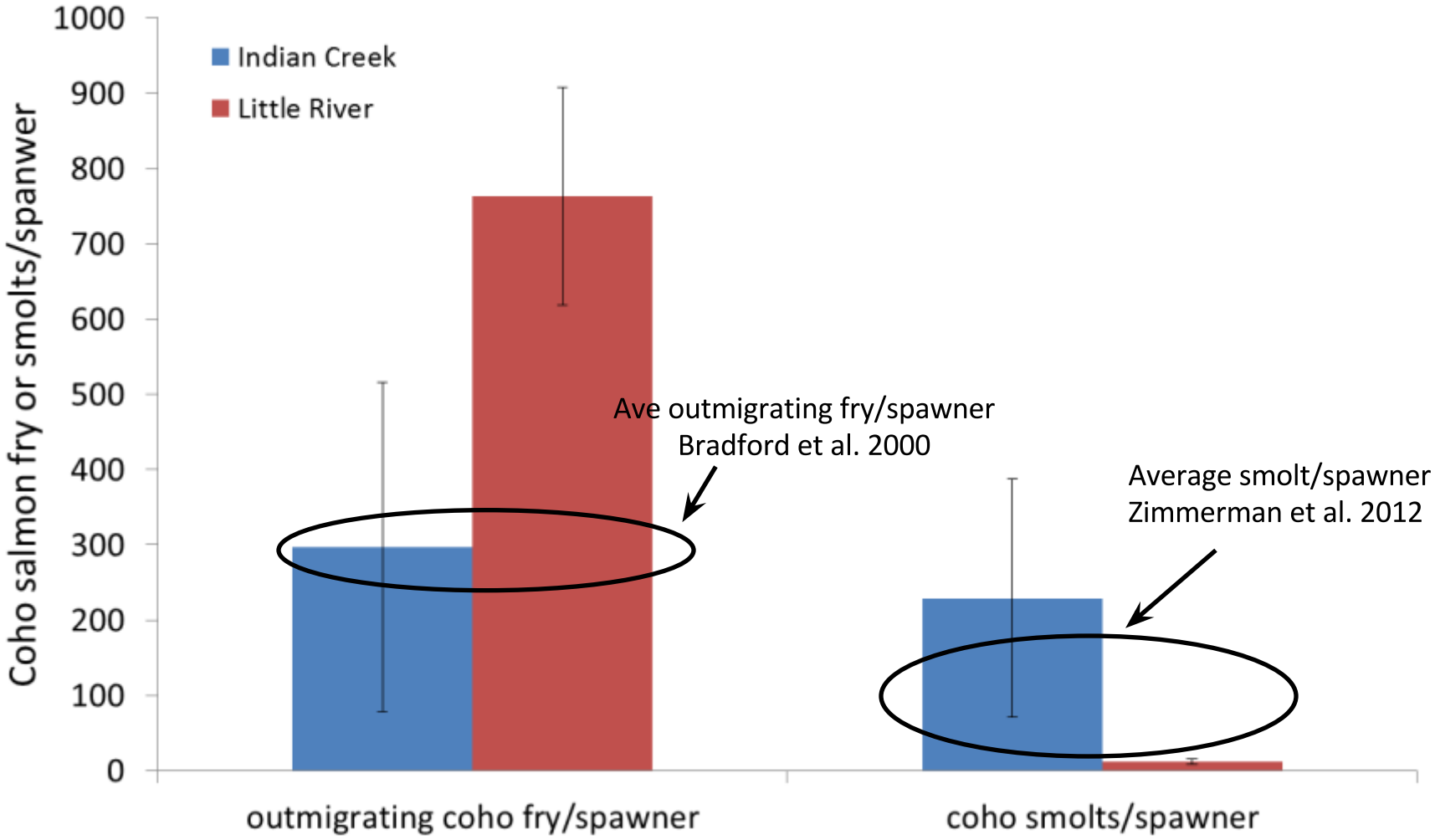




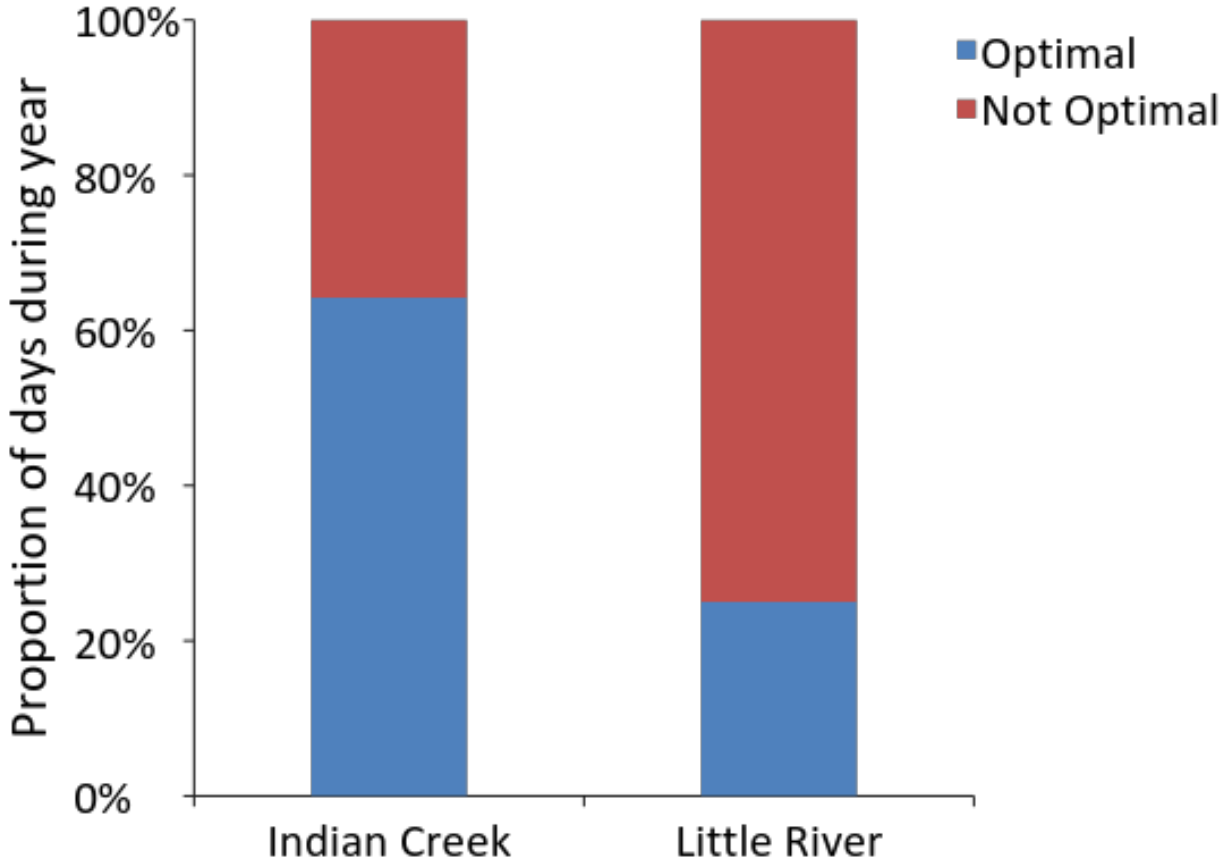
Elwha River smolt trap locations



Juvenile coho salmon productivity in the middle Elwha River - Little River v. Indian Creek



Optimal growing temperatures (9 to 13°C) middle Elwha River - Little River v. Indian Creek



Growth period for Indian Creek – April through September (6 months)
Growth period for Little River – July through September (3 months)

2013 middle Elwha River fish recolonization highlights

- First documented lamprey above Elwha dam

- First documented sockeye salmon in Indian Creek

- First documented summer steelhead in Little River

2013 middle Elwha River fish recolonization highlights

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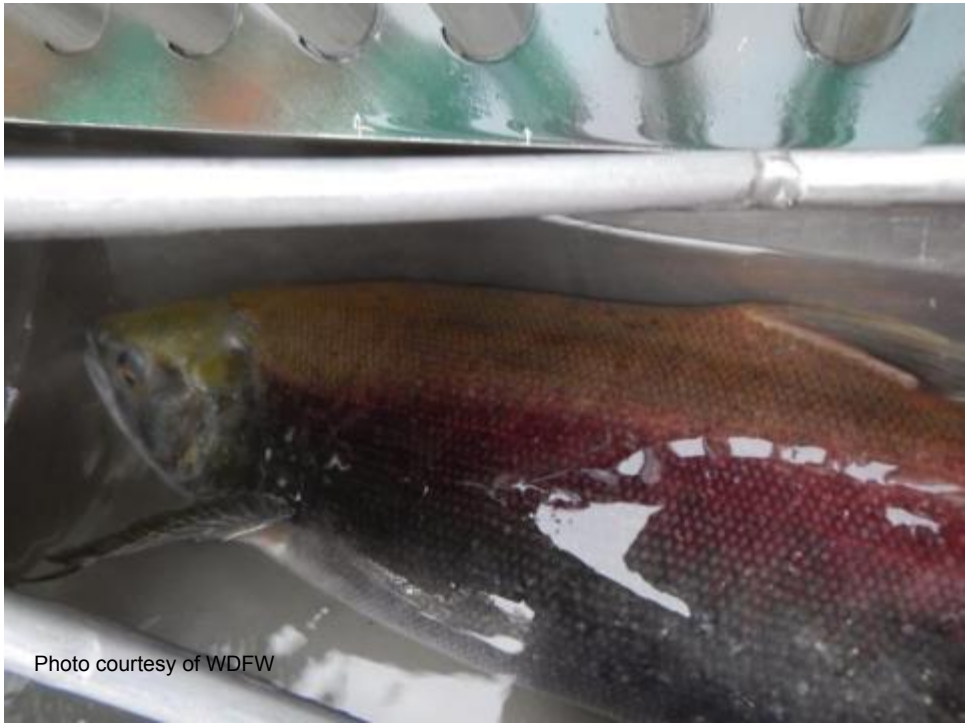


- First documented summer steelhead in Little River

2013 middle Elwha River fish recolonization highlights

- First documented lamprey above Elwha dam.
- First documented sockeye salmon in Indian Creek
- First documented summer steelhead in Little River

How has the benthic foodweb changed in the Elwha River?

Consumers
Resident Fish

Secondary Producers
Invertebrates

Direct
(tissue & eggs)

Spawners
Anadromous

Primary Producers
Periphyton

Indirect
(nutrients)

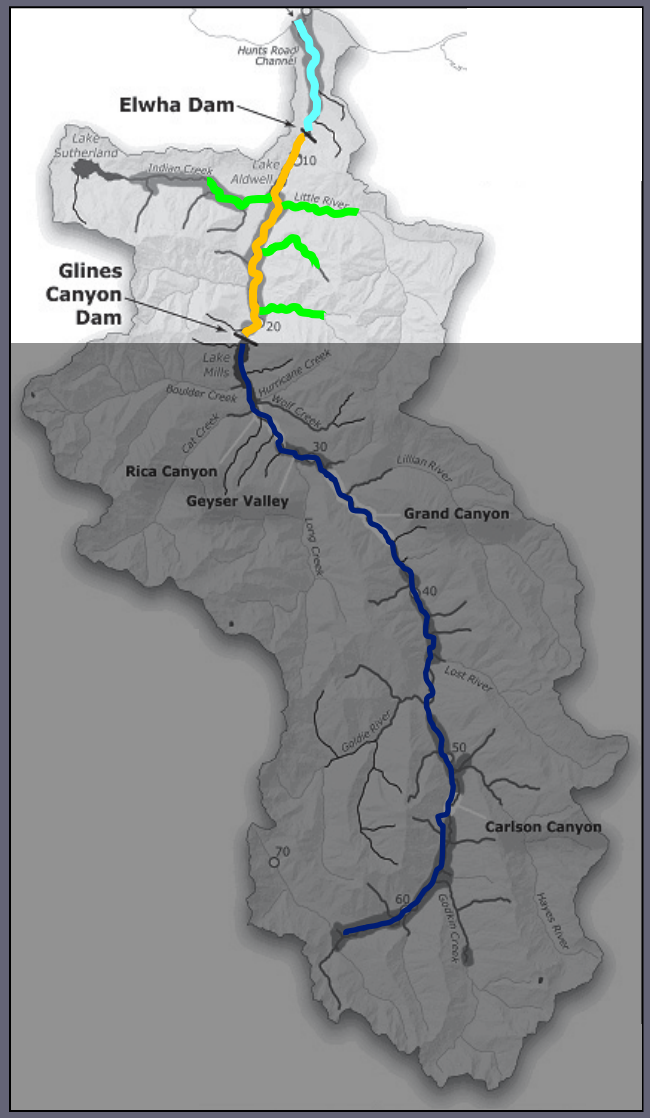
Physical Habitat

Water Chemistry

Sarah Morley, NOAA
Jeff Duda, USGS

Photos: J. McMillan, A. Draut

Study design to determine how the benthic foodweb will change with increased sediment in the Elwha River



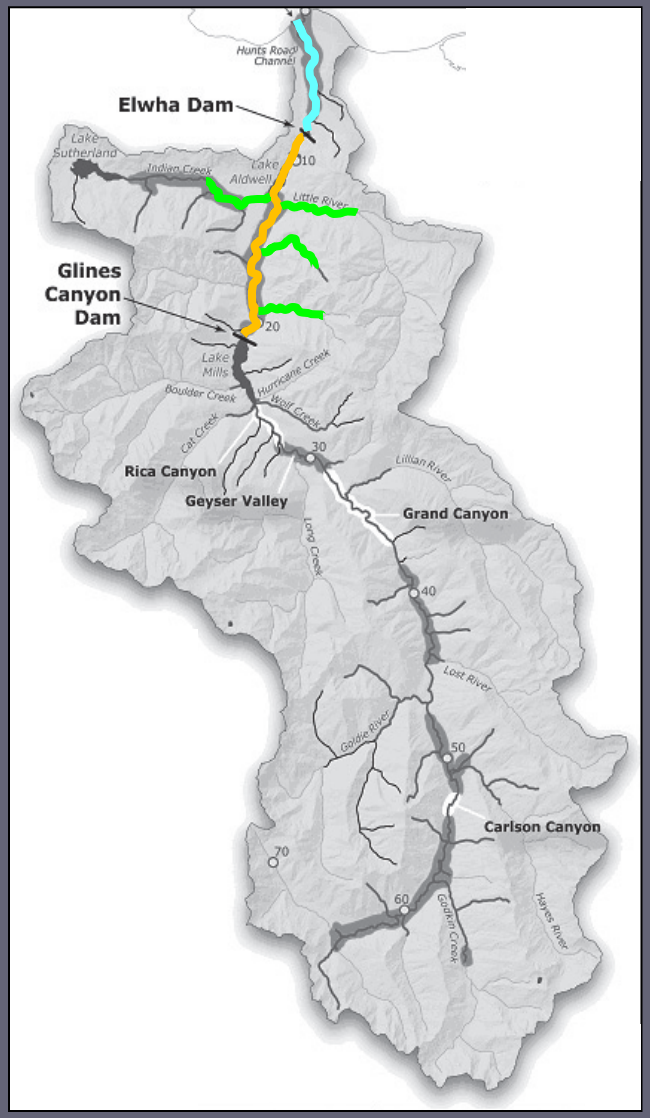
River sections: Below
Between
Above

Habitat types: Mainstem
Side channels
Tributaries

Pre-removal: 2004-2011

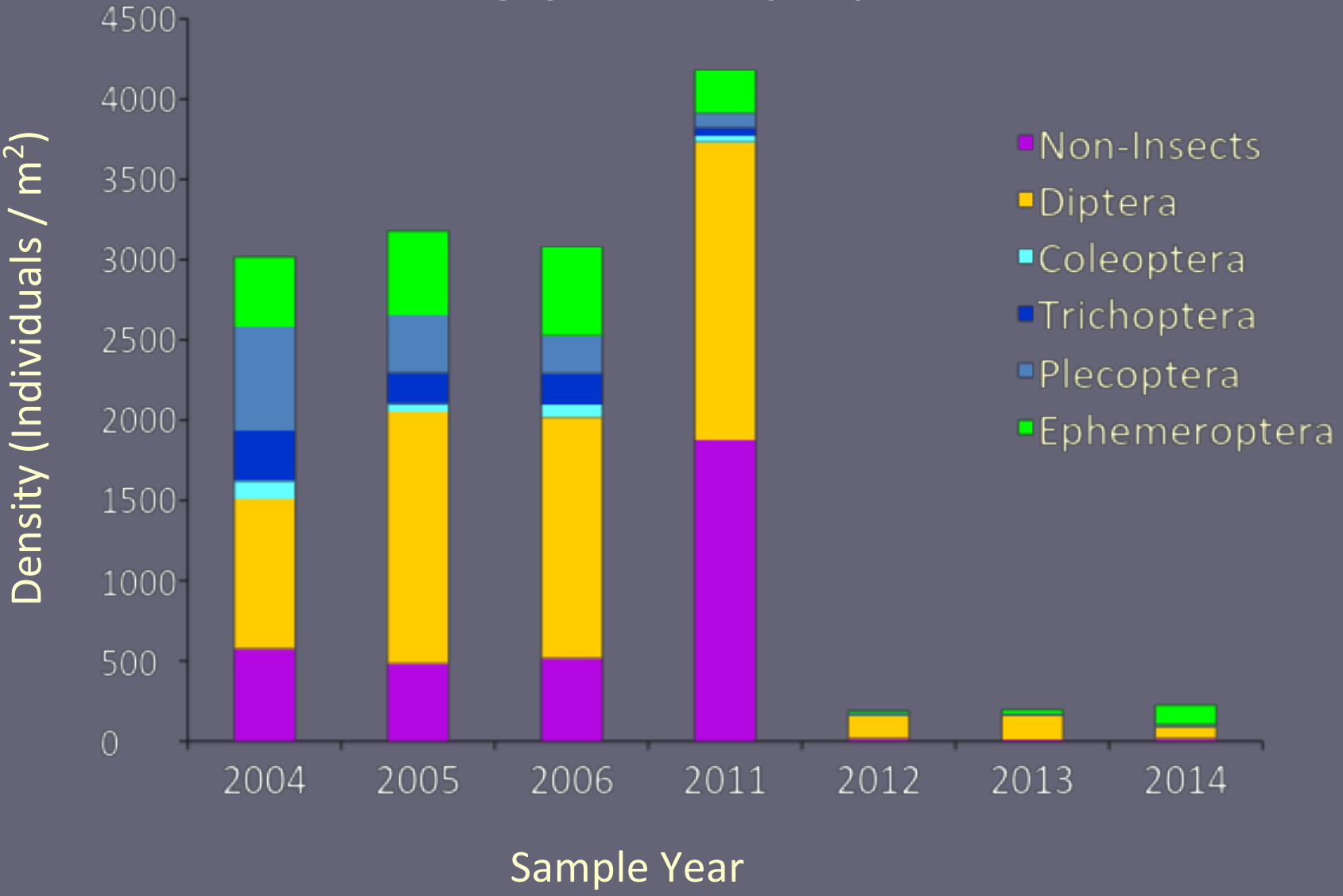
During-removal: 2012-2014

Benthic Invertebrate Densities – Pre vs. During Removal



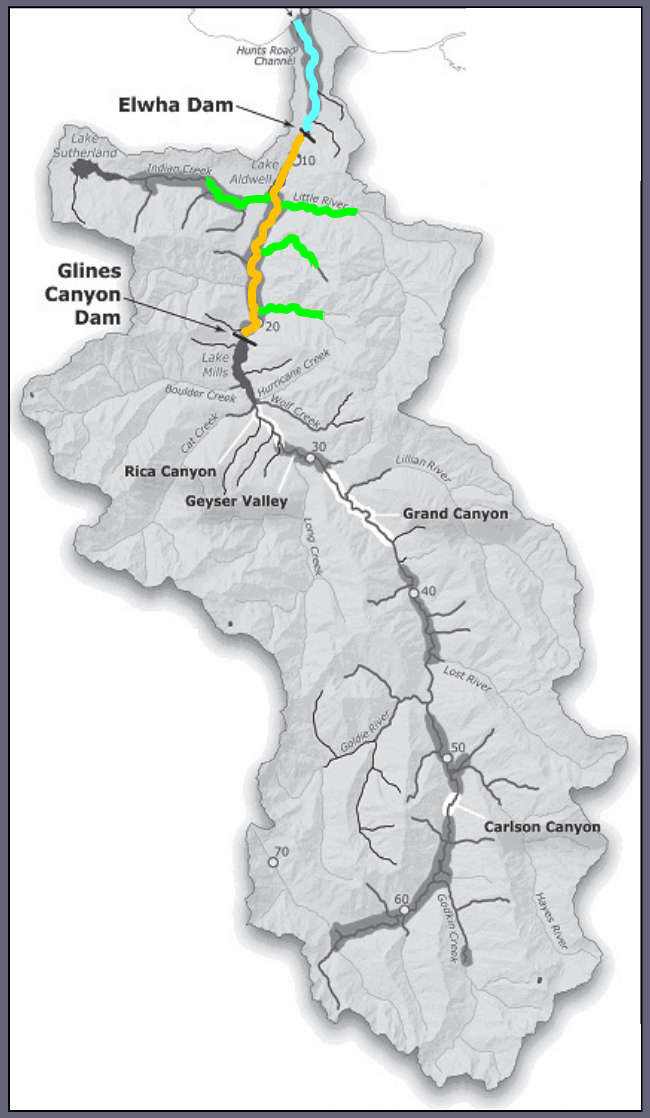
Benthic Invertebrate Taxonomic Composition

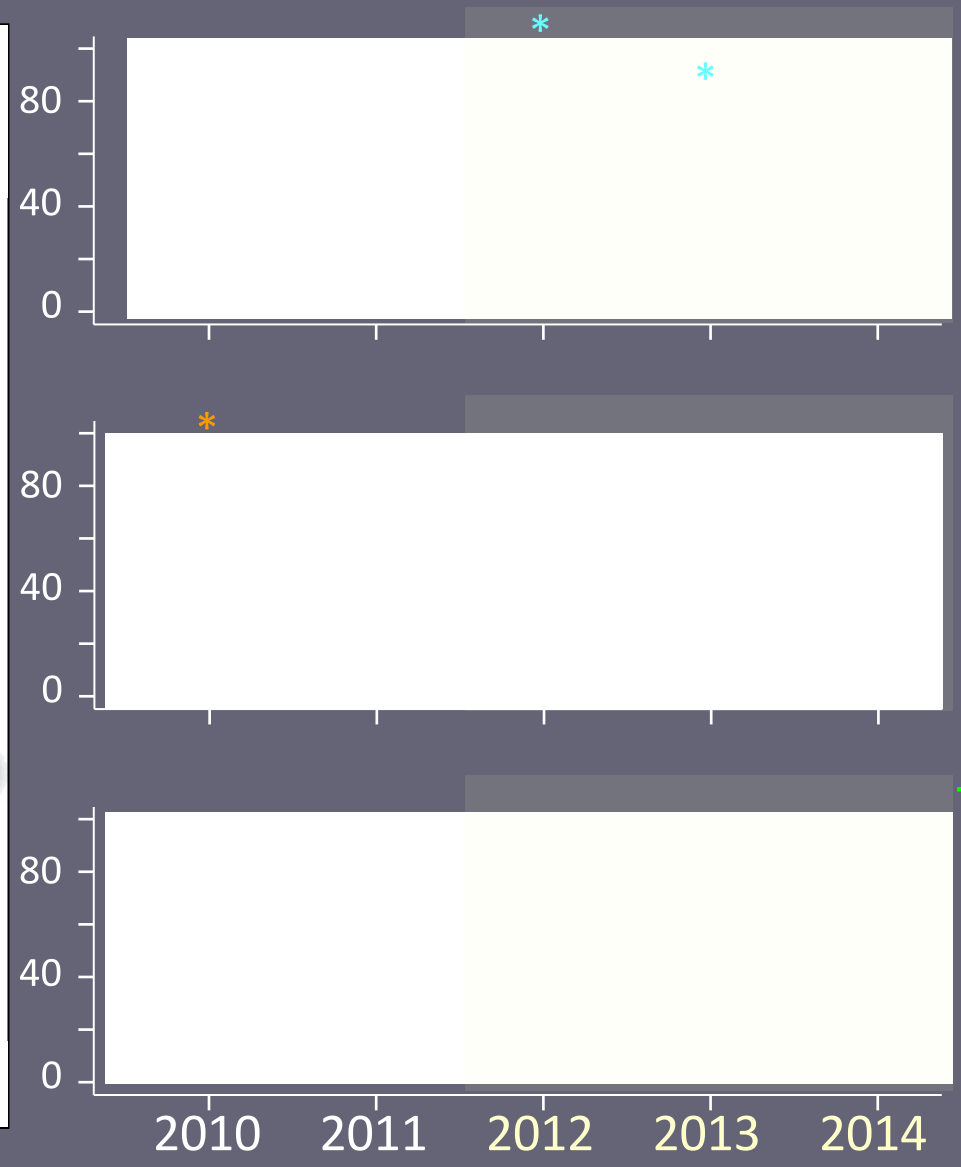
Below Elwha Dam



Diet Results

Juvenile Salmonid (*O. mykiss*) Diet – % Terrestrial





* $P < 0.05$

Elwha River dam removal & salmon recolonization
Revegetation & Terrestrial linkages

- Replanting & revegetation successful in fine sediments but not in coarse sediments.
  - J. Chenowith, NPS & M. McHenry, LEKT

- Dippers eating salmon eggs during non-breeding season (Spring/Fall).
  - C. Tonra, OSU & S. Morley, NOAA

- MDN signal in river otters correlated to the proportion of time spent areas where anadromy and marine resources are present.
  - K. Sager-Fradkin, LEKT

Elwha River dam removal & salmon recolonization
The former reservoirs

- Elwha and Glines canyon dam removal complete.
- ~50% of total stored sediment has been released as of October of 2013.
- Reservoirs being re-vegetated both naturally and with restoration efforts.

Elwha River dam removal & salmon colonization
Nearshore, main stem, & floodplains

- Delta at river mouth is prograding ~ 2km into the Strait of Juan De Fuca.
- ~10% of sediment stored in-river.
- Main stem aggraded (~1-2m), gravels bars developed, now seeing a large increase in wood accumulation.
- Floodplain channels filled with sediment.
- Floodplain surface now accumulating sediment.

Elwha River dam removal & salmon recolonization

- Adults are making it past old Elwha Dam site.
- Coho, steelhead & Chinook salmon redds are increasing each year in the middle Elwha River.
- Juveniles are dispersing to colonize new areas.
- Salmon productivity varies as a function of local environmental conditions.
- New species and life histories are being documented.

Elwha River dam removal & salmon recolonization
Benthic foodwebs

- Benthic invertebrate densities have been reduced 95% in the Lower Elwha
- Major shift in benthic invertebrate composition
- Juvenile O. mykiss relying more on terrestrial prey sources

Goals, opportunities, & challenges

- Goal
  - Document ecosystem response to dam removal in the Elwha River basin
- Challenges
  - Coordination, organization, consistent resources to monitor.
  - How to translate a case study into lessons learned for other dam removals
- Opportunities
  - Lessons learned for other dam removals

San Clemente reroute & dam removal, Carmel River, CA

CALIFORNIA AMERICAN WATER

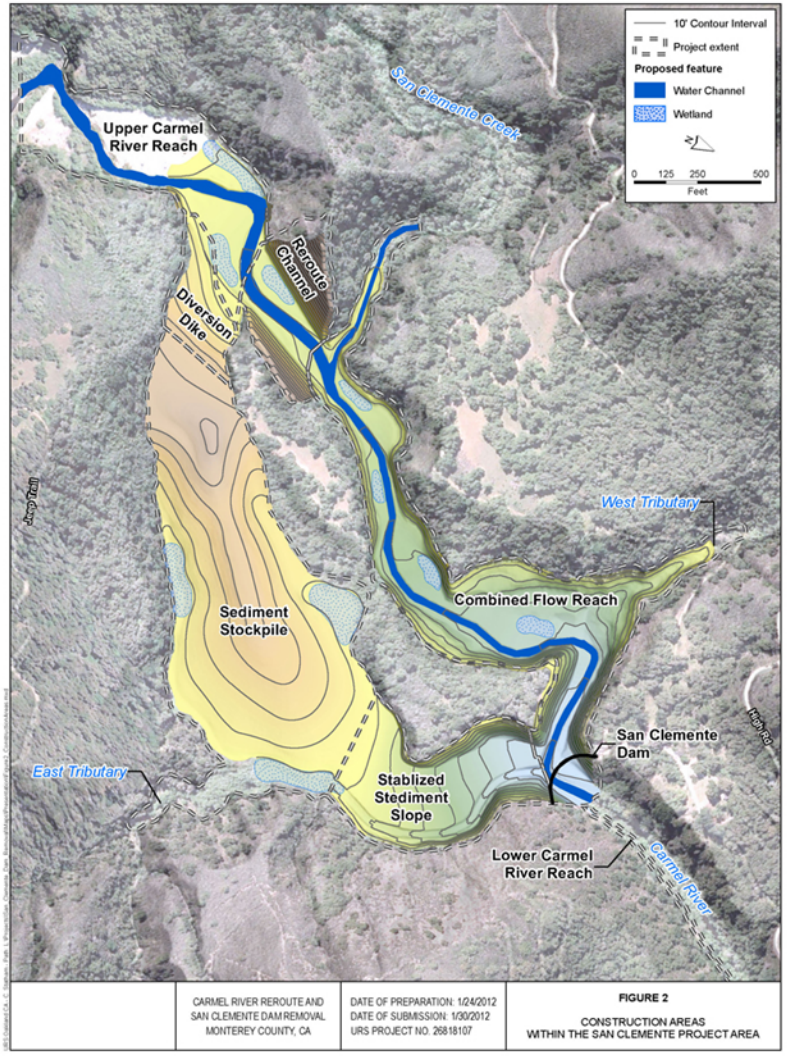
Coastal Conservancy

NOAA

Goals, opportunities, & challenges

- "Without monitoring and assessment, we have no way to determine when changes to management are needed."

- Schindler, D.E. & R. Hilborn. 2015. Prediction, precaution, and policy under global change. Science 347: 953-954.



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Coastal Conservancy

NOAA

Thank you

Where to Find Additional Information

USGS Scientific Investigations Report, 2011. Coastal Habitats of the Elwha River, Washington: Biological and Physical Patterns and Processes Prior to Dam Removal.
http://pubs.usgs.gov/sir/2011/5120/pdf/sir20115120.pdf

Northwest Science Special Issue, 2008, Vol. 82: Dam Removal and Ecosystem Restoration in the Elwha River Watershed, Washington State.
http://www.bioone.org/toc/nwsc/82/sp1

www.elwhainfo.org

www.nps.gov/olym/naturescience/elwha-ecosystem-restoration

http://wabc-afs.org/w/wp-content/uploads/downloads/2012/11/WA-BC_Fall-Newsletter_Nov-5th-2012.pdf

East, Amy E., et al. 2014. Large-scale dam removal on the Elwha River, Washington, USA: River channel and floodplain geomorphic change. Geomorphology

Gelfenbaum, Guy, et al. 2015. Large-scale dam removal on the Elwha River, Washington, USA: coastal geomorphic change. Geomorphology

Magirl, Christopher S., et al. 2015. Large-scale dam removal on the Elwha River, Washington, USA: Fluvial sediment load. Geomorphology